



*Larry Hogan, Governor*  
*Boyd Rutherford, Lt. Governor*  
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# **Quality Assurance Project Plan**

**for the**  
**Maryland Department of Natural Resources**  
**Chesapeake Bay**  
**Shallow Water Quality Monitoring Program**  
**for the period July 1, 2019 - June 30, 2020**

1 July, 2019

**DRAFT**

**Quality Assurance Project Plan for the  
Maryland Department of Natural Resources  
Chesapeake Bay Shallow Water Quality Monitoring Program  
for the period July 1, 2019 – June 30, 2020**

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Larry Hogan, Governor

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## ACRONYMS AND ABBREVIATIONS

AA	- Autoanalyzer
AMQAW	- Analytical Methods and Quality Assurance Workgroup (a workgroup of the Chesapeake Bay Program's Monitoring Subcommittee)
BGA	- Blue-Green Algae
C	- Carbon
CBP	- EPA's Chesapeake Bay Program
CBPO	- EPA's Chesapeake Bay Program Office
CBL	- University of Maryland's Chesapeake Biological Laboratory
CDMA	- Code Division Multiple Access
Chl	- Chlorophyll
CIMS	- Chesapeake Information Management System
cm	- Centimeter
CSSP	- Coordinated Split Sample Program
d	- Day
DI	- Deionized
DIWG	- Data Integrity Workgroup (a workgroup of the Chesapeake Bay Program, formerly AMQAW)
DNR	- Maryland Department of Natural Resources
DO	- Dissolved Oxygen
DU	- Designated Use
EM	- Emission
EPA	- U.S. Environmental Protection Agency
EST	- Eastern Standard Time
EX	- Excitation
FGDC	- Federal Geographic Data Commission
FNU	- Formazin Nephelometric Units
FS	- Full Scale
g	- Gram
h	- Hour
ITAT	- Integrated Trends Analysis Team
$K_d$	- Diffuse Attenuation Coefficient for Downward Irradiance
L	- Liter
m	- Meter
MDE	- Maryland Department of the Environment
MDH	- Maryland Department of Health
min.	- Minute
mg	- Milligram
ml or mL	- Milliliter
mm	- Millimeter
mS	- Millisiemens
mV	- Millivolts
N	- Nitrogen
NASL	- Nutrient Analytical Services Laboratory
NERR	- National Estuarine Research Reserve
NH <sub>4</sub>	- Ammonium
NIST	- National Institute of Science and Technology
nm	- Nanometer
no.	- Number
NO <sub>2</sub>	- Nitrite

NO <sub>23</sub>	- Nitrate + Nitrite
NO <sub>3</sub>	- Nitrate
NOAA	- National Oceanic and Atmospheric Administration
NTU	- Nephelometric Turbidity Units
OD	- Optical Density
ODO	- Optical Dissolved Oxygen
P	- Phosphorus
PAR	- Photosynthetic Active Radiation
PC	- Particulate Carbon (Organic)
PC	- Personal Computer
PE	- Phycoerythrin
PIP	- Particulate Inorganic Phosphorus
PN	- Particulate Nitrogen
PO <sub>4</sub>	- Phosphate
PP	- Particulate Phosphorus
ppt	- Parts Per Thousand
QA	- Quality Assurance
QAO	- Quality Assurance Officer (Unless otherwise noted, this refers to the DNR QAO)
QAPP	- Quality Assurance Project Plan
QA/QC	- Quality Assurance/Quality Control
QC	- Quality Control
R/V	- Research Vessel
RFU	- Relative Fluorescence Units
SAS	- Statistical Analysis System
Sat%	- Percent Saturation
SAV	- Submerged Aquatic Vegetation
SpCond	- Specific Conductance
STAR	- Scientific, Technical Assessment and Reporting Team
TCP/IP	- Transmission Control Protocol/Internet Protocol
TDN	- Total Dissolved Nitrogen
TDP	- Total Dissolved Phosphorus
TMAW	- Tidal Monitoring and Analysis Workgroup
TMDL	- Total Maximum Daily Load
TN	- Total Nitrogen
TP	- Total Phosphorus
TPP	- Total Particulate Phosphorus
trib	- Bay Tributary
TSS	- Total Suspended Solids
TVS	- Total Volatile Solids
µg	- Microgram
USDI	- U.S. Department of the Interior
USGS	- U.S. Geological Survey
VIMS	- Virginia Institute of Marine Science
VSS	- Volatile Suspended Solids
YSI	- Yellow Springs Instruments
°C	- Degrees Celsius

## **PREFACE**

This document is intended to describe in detail the activities conducted under the Shallow Water Monitoring Program of the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program. This program includes water quality mapping and continuous monitoring in the tidal tributaries of Maryland's Chesapeake Bay. This program is funded through The State of Maryland, the United States Environmental Protection Agency Chesapeake Bay Program, the National Oceanic and Atmospheric Administration Chesapeake Bay Office and National Estuarine Research Reserve System program, the Dominion Foundation, the National Fish and Wildlife Foundation, the Oyster Recovery Partnership, the National Aquarium in Baltimore, the National Marine Sanctuary Foundation, and The Nature Conservancy.

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## **DISTRIBUTION LIST**

This Quality Assurance Project Plan is available on-line by using publication type 'Quality Assurance Project Plan' to search the Monitoring News and Reports page of the Maryland Department of Natural Resources (DNR) Eyes on the Bay website:

<http://eyesonthebay.dnr.maryland.gov/eyesonthebay/stories.cfm>.

## 1. INTRODUCTION AND PROJECT DESCRIPTION

### 1.1 Background

The Chesapeake Bay Program Monitoring and Analysis Subcommittee's Tidal Monitoring and Analysis Workgroup (TMAW) had undertaken the role of redesigning the Tidal Monitoring Network. The Tidal Monitoring Network focuses on meeting the Water Quality Protection and Restoration goals and objectives of the Chesapeake 2000 Agreement. In 2014, the Scientific, Technical Assessment & Reporting (STAR) team formed the Integrated Trends Analysis Team (ITAT). Many TMAW goals have been subsumed by similar ITAT goals. Water quality monitoring information is used to define nutrient and sediment conditions necessary to protect living resources (water quality to support crabs, oysters, and fish) and vital habitats (water quality to support submerged aquatic vegetation - SAV). The information is also used to develop and assess water quality criteria with the goal of removing the Bay and its tidal rivers from the list of impaired waters. Water quality information is required to support refinement, calibration and validation of the Chesapeake Bay Eutrophication and Watershed Models.

As part of the Tidal Monitoring Network, the Maryland Department of Natural Resources (DNR) and its federal, state and local partners are working together to implement a comprehensive and coordinated monitoring program to assess the Bay's shallow water habitats, which is required by the development of the new water quality criteria. Until 2002, sparse water quality data were collected in shallow portions of Chesapeake Bay and its tributaries. This presented a major gap in data for use in evaluation of new Designated Use Areas and Water Quality Criteria.

Through the 2019-2020 Shallow Water Quality Monitoring Program, water quality and habitat measurements will be made using water quality mapping technology and fixed continuous monitors to provide characterization of shallow water habitats that are key to living resources. The goal of the program is to conduct assessments for a minimum of three years in each of the Chesapeake Bay segments. Water quality mapping was piloted by the states of Maryland and Virginia, as well as academic researchers, and was extensively tested by Maryland in the Magothy River, Severn River, and Tangier Sound from 1999 to 2002. Continuous monitoring was initially implemented by Maryland in the Pocomoke River to monitor water quality in response to the *Pfiesteria piscicida* outbreak in 1998. The implementation of shallow water monitoring technology is coordinated between States and their partners employing similar equipment and methodology to ensure bay-wide compatibility and comparisons. Detailed information describing these technologies and the 1998 - 2019 results can be found on DNR's Eyes on the Bay web site (<http://www.eyesonthebay.net/>.)

### CONTINUOUS MONITORING

Maryland DNR is conducting Continuous Monitoring in 13 Chesapeake Bay segments in 2019 and Water Quality Mapping in two segments (Figure 1, Table 1). This design comprises monthly water quality mapping cruises with three to four continuous monitoring sites in each segment. Monitoring covered in this QAPP will primarily be conducted April through October 2019.

Continuous monitoring sites (Table 3) will be deployed by the end of April, 2019 and most will be removed by the end of October, 2019 in each of 13 Maryland Chesapeake Bay segments (Figure 1). Sites in the Patapsco River, Potomac River, Harris Creek, Gooses Reef, as well as sites associated with the National Estuarine Research Reserve (NERR) System will be deployed year-round, weather permitting. Site location will be adjusted in 2020 to relocate sites where three-year assessments are complete. Sites are generally located in shallow water habitats to provide spatial diversity within the segment. Where applicable, continuous monitoring sites will be used as calibration sites for water quality mapping cruises. Most continuous monitoring sites will be serviced on a bi-weekly basis unless water quality readings demonstrate that weekly intervals are required. Some stations equipped with more advanced monitoring

technology that allows for longer deployments will be serviced monthly. One deep water station will also be serviced on a monthly basis. Results since 2003 indicate that the YSI™ 6600 EDS (Extended Deployment Systems) or V2 model sondes can be deployed for two-week periods throughout most of the annual sampling period without compromising data integrity. YSI™ EXO2 model sondes are equipped with more advanced anti-fouling technology and can, therefore, be deployed for up to a month without compromising data integrity. At the Gooses Reef deep water station, deployment will be for thirty days based on the assumption that less biofouling occurs in deeper water. Sites deployed year round will be exchanged monthly between November and March under the assumption that less biofouling, which may compromise data integrity, occurs during cold weather months. Should both of these assumptions prove untrue, deployment duration will be re-evaluated.

During each site visit, instruments in the water will be checked against the replacement instrument, as well as another Hydrolab™ or YSI™ instrument to provide a third comparison. A discrete water sample will be collected for chlorophyll, pheophytin, and turbidity (using total suspended solids---TSS) calibration during each site visit. At two sites, a full suite of nutrient samples (Table 9), including volatile suspended solids (VSS) and particulate inorganic phosphorus (PIP), will also be collected. The same protocols and naming conventions outlined in the Chesapeake Bay Mainstem 117(e) grant and the approved Quality Assurance Project Plan (QAPP) for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program - Chemical and Physical Properties Component will be observed. An additional five sites associated with the NERR System, as well as one site associated with a proposed National Marine Sanctuary, will have a subset of nutrients (VSS, NH<sub>4</sub>, PO<sub>4</sub>, NO<sub>2</sub>, NO<sub>23</sub>, TN, TP) collected. At three additional sites deployed in proximity to an oyster sanctuary in Harris Creek, alkalinity will also be collected. No samples will be collected by DNR at two sites deployed adjacent to the National Aquarium in Baltimore.

A light reading and Secchi depth reading will also be collected. Light readings will be measured using LI-COR™ equipment, comprised of a deck reference sensor and a LI-COR™ flat sensor. Simultaneous deck and submersed measurements will be recorded to assess the variability in incident surface irradiance due to changing atmospheric conditions. A detailed description of light measurements is included in Appendix 4.

The replacement instrument will then be left at the site for approximately two to four weeks (see above). The instrument that was at the site for the previous weeks will be delivered to the field office for data download, post-calibration, cleaning and servicing. Detailed instrument calibration procedures are included in Appendix 5.

## WATER QUALITY MAPPING

Water quality mapping (DataFlow) is a system, usually deployed in a small boat, of geospatial equipment and water quality probes that measure water quality parameters from a flow-through stream of water collected near the water's surface. This system allows data to be collected rapidly (approximately every four seconds) while the boat is traveling at speeds of up to 25 knots. Since the system is compact enough to deploy from a small boat, it allows sampling in shallow water and the ability to map an entire small tributary in less than one day. Water is pumped through a ram (pipe), over the sensors, and then discharged overboard. Sensors are deployed on a YSI 6600 Sonde with a flow-through chamber. A Raymarine A70D or Garmin model GPSMAP168 sounder chart plotting receiver and depth-finder global positioning system (GPS) is also part of the system. Each water quality measurement is associated with a date, time, water depth, and GPS coordinate (NAD83) reported to six decimal places. A preliminary 2019 survey schedule is presented in Table 2. The eight water quality parameters measured are: water temperature, specific conductance, salinity (calculated from specific conductance and water temperature), dissolved oxygen, pH, turbidity (NTU), fluorescence, and total chlorophyll (estimated from fluorescence).

All parameters will follow the same naming conventions as outlined in the existing Chesapeake Bay Mainstem 117(e) grant and approved Water Quality Project Plan.

Additional results will be acquired in central segments CB4MH and CB5MH using a larger vessel, typically the R/V Kerhin. Due to logistical issues, the monthly central CB4MH larger vessel surveys may occur on different days than the Northern and Southern small boat, and Eastern CB5MH surveys. Central CB4MH and CB5MH, Eastern CB5MH, Northern CB4MH, and Southern CB4MH results will be aggregated to create water quality parameter spatial maps for each of the months sampled. Western CB5MH, conducted in St Jerome Creek and Southward to Point Lookout, will be mapped separately.

Larger vessel water quality mapping sonde data acquisition will be accomplished by flowing Bay water from 0.5m depth across sonde sensors in a YSI flow-cell and merging the sonde file with the vessel navigation log file. Typical large vessel cruising speed is 28 km/hr (15 kts). Measurements are made approximately every four seconds, or 17 meters (56 feet).

The larger survey vessels are built with through hull fittings (sea-cocks) located 0.5m below the waterline. The fittings are means of safely controlling the flow of water from outside the vessel hull into the vessel. At the beginning of each survey, the DATAFLOW sonde is activated. Bay water will be flowed from the sea-cock across the DATAFLOW sonde sensors in the YSI Flow-cell. A vessel navigation log file will be started and vessel coordinate and speed values will be acquired from the vessel geographic positioning system. At the end of the survey, the navigation file will be copied and uploaded to a data server. After sonde post-calibration, the sonde file will be copied and uploaded to a data server.

Two larger vessels may serve as survey platforms during the 2019- 2020 water quality mapping season, R/V Kerhin and R/V Rachel Carson. Vessel lengths are, respectively, 49 and 81 feet. R/V Kerhin will use a program named GPSU to log navigation data from a Simrad HS70 GPS compass, and depth readings from a Furuno FCV 1100 L echo sounder. R/V Rachel Carson will use a program named Electronic Nautical Chart to log navigation data from a Northstar 952X Differential GPS.

Water quality mapping uses the same YSI 6600 instrument package as used for the continuous monitoring program. Detailed instrument calibration procedures for the instrument are included in Appendix 6. Each segment will be monitored once a month (Figure 1, Table 2), April through October.

During each water quality mapping cruise, five calibration samples are generally collected for use in the development of regressions for chlorophyll, turbidity, total suspended solids, and light attenuation. Sample collection stations are listed in Table 4. Samples for total suspended solids and chlorophyll, as well as a light reading and Secchi depth reading, will also be collected at each calibration station. Light readings will be measured using LI-COR™ equipment, comprised of a deck reference sensor and a LI-COR™ flat sensor. Simultaneous deck and submersed measurements will be recorded to assess the variability in incident surface irradiance due to changing atmospheric conditions. A detailed description of light measurements is included in Appendix 4.

Three calibration samples will be collected each month during CB5MH Eastern surveys. Two calibration samples will be collected monthly on CB5MH Western surveys. Calibration samples will be collected at fixed stations during monthly Chesapeake Bay mainstem water quality monitoring project surveys conducted on R/V Kerhin or R/V Rachel Carson. DataFlow calibration samples will not be collected during the larger vessel CB4MH and CB5MH surveys in order to consolidate MDDNR project sampling efforts.

**Table 1.** Shallow-water monitoring for 2019: Bay segment, sample type(s) and Designated Uses (DU) for which the collected data will be used to assess water quality criteria.

Tributary	Segment Name	Sample Type(s)	Shallow Water DU			Open Water DU			Spawning/ Nursery DU			Deep Water DU		
			Chl <i>a</i>	K <sub>a</sub>	D.O.	Chl <i>a</i>	K <sub>a</sub>	D.O.	Chl <i>a</i>	K <sub>a</sub>	D.O.	Chl <i>a</i>	K <sub>a</sub>	D.O.
			Back R.	BACOH	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO
Bush R.	BSHOH	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	*	*	*
Chesapeake Bay	CB1TF	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	*	*	*
	CB3MH <sup>1</sup>	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	NA	NA	NO
	CB4MH <sup>1</sup>	Cont. Monit.	YES	YES	YES	YES	NA	YES	*	*	*	NA	NA	YES
		Water Quality Mapping												
	CB5MH <sup>1</sup>	Cont. Monit.	YES	YES	YES	YES	NA	YES	*	*	*	NA	NA	YES
Water Quality Mapping														
Choptank R.	CHOMH1	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	*	*	*
Patapsco R.	PATMH <sup>1</sup>	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	NA	NA	NO
Patuxent R.	PAXTF	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	*	*	*
	WBRTF	Cont. Monit.	NO	NA	NO	NO	NA	NO	NO	NA	NO	*	*	*
Potomac R.	POTOH	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	*	*	*
	POTMH <sup>1</sup>	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	NA	NA	NO
Wicomico R.	WICMH	Cont. Monit.	NO	NO	NO	NO	NA	NO	NO	NO	NO	*	*	*

YES: Data from this project are expected to be used to assess these criteria

NO: Data from this project cannot be used to assess these criteria.

NA: Criteria does not apply to this Designated Use category.

\*: This segment does not contain this Designated Use

<sup>1</sup> CB3MH, CB4MH, CB5MH, PATMH, and POTMH also have Deep Channel Designated Use for D.O.

**Table 2.** Water Quality Mapping Cruise Schedule (April through October 2019).

<b>River System</b>	<b>April</b>	<b>May</b>	<b>June</b>	<b>July</b>	<b>Aug</b>	<b>Sept</b>	<b>Oct</b>
Middle Central Chesapeake <sup>1</sup> (CB4MH)	11/16	21/21	6/4	9/9	6/6	12/17	10/16
Lower Central Chesapeake (C5MH)	10/15	20/20	4/3	8/8	5/5	11/16	9/15

<sup>1</sup> Water Quality Mapping for CB4MH and CB5MH will be conducted using separate cruises for shallow waters near shore and one for the deeper mainstem. First date listed is near shore cruise date. Second date listed is mainstem cruise date.

The dates defined within this scope of work are for implementation of the shallow water monitoring for calendar year 2019 and reflect work to be funded and completed within the budget period of July 1, 2019 - June 30, 2020.

DNR will provide matching funds and will solicit other funding sources to expand shallow water monitoring capabilities. DNR will also provide staff, equipment and other resources to enhance shallow water monitoring with its partners and will coordinate with existing long-term water quality monitoring programs to ensure better understanding of estuarine processes.

## **1.2 Objectives and Problem Definition**

The objectives of the Shallow Water Monitoring Program are to 1) assess the Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow and open water habitats, 2) determine attainment or non-attainment of shallow water and open water habitats for their designated uses, 3) provide spatially and temporally intensive data in shallow water habitats to improve water quality mapping using interpolation, 4) assess SAV habitats and identify potential SAV restoration sites, 5) provide information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows) in shallow water and open water environments, and 6) provide information for calibrating the Chesapeake Bay Eutrophication and Watershed Models.

As objectives are achieved, they will provide the basis for management decisions. For example, if the monitoring results determine that a water body is out of attainment, the water body will be listed in the 305(b) report to the U.S. Environmental Protection Agency. If the causes of non-attainment are determined to be anthropogenic, the water body will be placed on the 303(d) list requiring a TMDL (total maximum daily load). Another example is the identification of potential SAV restoration sites. Shallow water monitoring data will be used by the SAV restoration strategy project to help select or eliminate sites from consideration for SAV restoration projects.

Spatially intensive water quality mapping provides information on variability and patchiness that is invaluable in establishing water quality criteria, and in determining attainment of those criteria. For example, spatial information on turbidity can be correlated to the spatial coverage of living resources such as bay grasses (SAV). This information can be used to determine and assess water clarity criteria necessary to support SAV growth, address the progress of meeting ambitious SAV restoration goals, and target specific areas for successful SAV restoration. Spatially intensive data can also help pinpoint localized areas of water quality concern, such as areas of low dissolved oxygen that can cause fish kills, and their possible links to nearby land uses or point sources. Spatial data can also be aggregated across watershed units to aid in the evaluation of entire systems.

Temporally intensive (continuous) monitoring provides information on the temporal variability of water quality. Continuous monitoring captures events that occur on short time scales (hours to days) or during times when it is impractical to deploy field crews. Continuous monitoring can capture early morning lows in dissolved oxygen as well as daytime and nighttime values of water quality parameters to provide scientists with the information necessary to fully assess instantaneous water quality criteria in shallow water habitats. Continuous monitoring provides early warning of potential harmful algal blooms and low-dissolved oxygen related fish kills, allowing managers to coordinate appropriate supplemental sampling (e.g., plankton sampling). Continuous monitoring is instrumental in documenting the water quality impacts of episodic storm events.

### **1.3 Sampling Design**

#### **1.3.1 Parameters**

Parameters measured *in situ* include turbidity, specific conductance (to calculate salinity), water temperature, dissolved oxygen, fluorescence (used to estimate total chlorophyll), pH and depth (see Appendices 9 and 10). *In situ* turbidity and chlorophyll fluorescence measurements are surrogates for  $K_d$  (light attenuation coefficient) and chlorophyll *a*, respectively; therefore, discrete measurements of photosynthetic active radiation (PAR) and chlorophyll *a* are needed to establish regression models that relate *in situ* turbidity to  $K_d$  and chlorophyll fluorescence to chlorophyll *a*. In addition, blue-green algal concentration (cells/mL or  $\mu\text{g/L}$ ) and Relative Fluorescence Units (RFUs) will be quantified at select sites by measuring phycoerythrin (marine and estuarine waters) pigment concentrations.

Grab samples that are filtered on site will be collected at water quality mapping calibration stations and at continuous monitoring stations. Processed samples will be taken and sent to the Chesapeake Biological Laboratory's Nutrient Analytical Services Laboratory for analysis. Samples from two Continuous Monitoring sites will be analyzed for the same suite of nutrients as those measured for the Chesapeake Bay Mainstem Program (chlorophyll *a*, pheophytin, total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, ammonium, total dissolved phosphorus, particulate phosphorus, orthophosphate, particulate carbon, total suspended solids and volatile suspended solids) plus particulate inorganic phosphorus. Samples from an additional five Continuous Monitoring sites associated with the NERR System, as well as one site associated with a proposed National Marine Sanctuary, will be analyzed for a subset of nutrients (TSS, VSS,  $\text{NH}_4$ ,  $\text{PO}_4$ ,  $\text{NO}_2$ ,  $\text{NO}_{23}$ , TN, TP), as well as chlorophyll. Samples from three additional Continuous Monitoring sites associated with an oyster restoration site in Harris Creek will be analyzed for alkalinity. In addition, Secchi depth and photosynthetic active radiation (PAR) measurements will be taken at calibration stations to calculate light attenuation ( $K_d$ ). See Appendix 4 for details of the procedure for calculating light attenuation. See next section (Methods and Performance Measures) for a list of all parameters and the methods associated with them.

#### **1.3.2 Spatial and Temporal Aspects**

Maryland DNR is responsible for conducting shallow water monitoring in 50 Chesapeake Bay Program segments. Each segment will be assessed for a three-year period. Available resources will dictate the number and locations of segments assessed. These segments will be prioritized considering the following factors:

- Need for making listing or delisting decisions
- Potential importance as restoration site for living resources (e.g., oysters, SAV)
- Importance as living resource habitat
- Modeling needs
- Availability of partners to share costs and labor
- Logistics and efficiency considerations
- Geographic, size, and habitat type representation/equitability considerations

- Determine effect of major management action (before/after)

Continuous monitoring instruments will be deployed at predetermined sites in Maryland's tidal tributaries. Continuous monitoring sampling sites are chosen to be representative of a tidal tributary's upstream and downstream conditions. Continuous monitoring sampling sites primarily utilize existing structures for instrument mounting (e.g., piers and pilings), so the location of such structures is taken into consideration when choosing sites. Additionally, areas of SAV restoration are also taken into consideration when choosing continuous monitoring sampling sites. Sampling sites for the 2019 season are depicted on the map in Figure 1.

Nine Chesapeake Bay tributary segments and four Chesapeake Bay mainstem segments have been identified for shallow water monitoring in Maryland in 2019, ranging from small to large systems with spatial coverage throughout Maryland (some systems have Continuous Monitors only):

- Back River (Sixth year of assessments for this small system on the Upper Western Shore)
  - Station located at Riverside.
- Bush River (Seventeenth year of monitoring for this small system on the Upper Western Shore)
  - Station located at Otter Point Creek (NERRS Site).
- Chesapeake Bay – CB1TF (Thirteenth year of monitoring for this large bay segment)
  - Station located at Havre de Grace.
- Chesapeake Bay – CB3MH (Sixteenth year of monitoring for this large bay segment)
  - Station located at Sandy Point South Beach.
- Chesapeake Bay – CB4MH (Tenth year of monitoring for this large bay segment)
  - Stations located at Gooses Reef, Dares Beach Pier, Arundel on the Bay, Taylor's Island, and Tilghman Island; Third year of Water Quality Mapping.
- Chesapeake Bay – CB5MH (Second year of monitoring for this large bay segment)
  - Stations located at Seashore Beach, Point Lookout, and Hoopers Island; Second year of Water Quality Mapping.
- Choptank River (Eleventh year of monitoring for this mid-sized system on the Eastern Shore)
  - Stations located in Harris Creek, plus a water quality vertical profiler in Harris Creek.
- Patapsco River (Twentieth year of monitoring for this large system on the Upper Western Shore)
  - Stations located at Masonville Cove and the National Aquarium in Baltimore.
- Patuxent River (Seventeenth year of monitoring for this large system in the Patuxent River Basin)
  - Stations located at Mataponi Creek (NERRS Site), Jug Bay (NERRS Site) and Iron Pot Landing (NERRS Site).
- Potomac River (Sixteenth year of monitoring in the Potomac River Basin)
  - Stations located at St George's Creek and Mallows Bay (Proposed National Marine Sanctuary. (Additional sites in Virginia maintained by Virginia DEQ, VIMS, and George Mason University).
- Wicomico River/Monie Bay (Fourteenth year of monitoring for this mid-sized system on the Lower Eastern Shore)
  - Station located at Little Monie Creek (NERRS Site).

DNR will also maintain a water quality vertical profiler for NOAA's Chesapeake Bay Office in the Tred Avon River, a tributary of the Choptank River. Data from this profiler may be obtained by submitting a request to NOAA's Chesapeake Bay Office.

Furthermore, DNR will maintain the water quality instruments associated with three buoys that are part of NOAA's Chesapeake Bay Interpretive Buoy System (CBIBS). These buoys are located near the mouth of the Severn River in the Central Chesapeake Bay, the mainstem Middle Central Chesapeake Bay, and the mouth of the Potomac River in the Lower Central Chesapeake Bay. More information and real-time data

can be found on the NOAA CBIBS website (<https://buoybay.noaa.gov/>). Calibration and nutrient data from CBIBS buoys can be downloaded through the Chesapeake Bay Program Water Quality Database ([https://www.chesapeakebay.net/what/downloads/cbp\\_water\\_quality\\_database\\_1984\\_present](https://www.chesapeakebay.net/what/downloads/cbp_water_quality_database_1984_present)).

Latitude and longitude values of continuous monitoring and water quality mapping calibration site locations for 2019 are provided in Tables 3 and 4. Detailed location data collected by GPS on water quality mapping cruises will be associated with each data point measured during the cruise and submitted to the Bay Program as part of routine data submissions.

**Table 3.** 2019 Continuous monitoring stations.

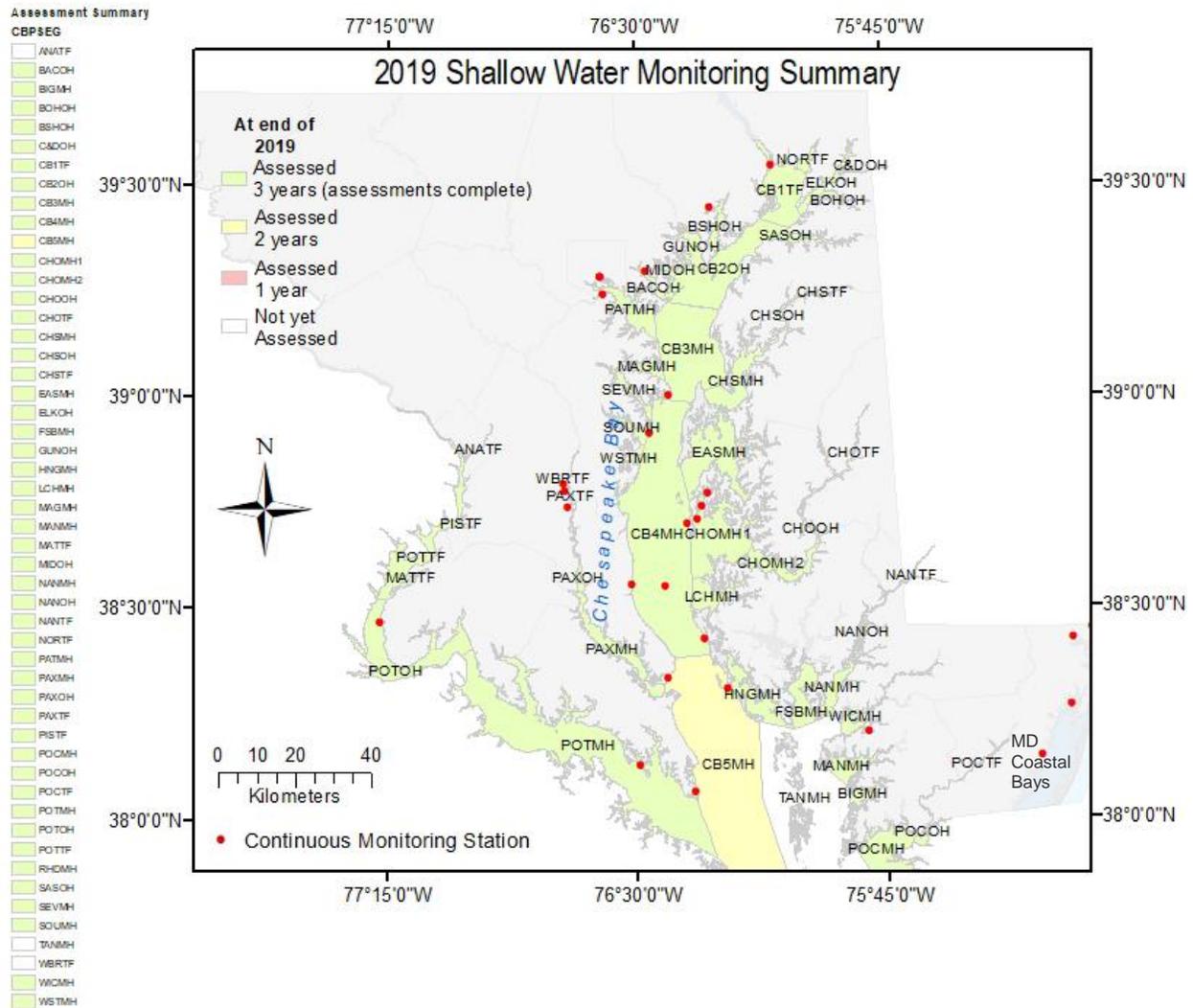
Tributary	Segment	Station Name	Station	Years deployed	LAT (NAD83)	LONG (NAD83)
Back River	BACOH	Riverside	XIF7918	2014 – present	39° 17.887' N	76° 28.218' W
Bush River	BSHOH	Otter Point Creek	XJG7035	2003 – present	39° 27.047' N	76° 16.474' W
Chesapeake Bay	CB1TF	Havre de Grace	XKH2949	2007 – present	39° 32.867' N	76° 05.088' W
	CB3MH	Sandy Pt. - South Beach	XHF0460	2004 – present	39° 00.450' N	76° 24.020' W
	CB4MH	Gooses Reef - Bottom	XEF3551	2010 - present	38° 33.375' N	76° 24.882' W
		Dares Beach Pier	XEE3691	2017 – present	38° 33.583' N	76° 30.924' W
		Arundel on the Bay	XGF5025	2017 – present	38° 55.005' N	76° 27.503' W
		Taylor's Island Pier	XDG5922	2018 – present	38° 25.888' N	76° 17.790' W
	CB5MH	Tilghman Island	XFF2293	2017 – present	38° 42.219' N	76° 20.718' W
		Hoopers Island	XCG8862	2018 - present	38° 18.804' N	76° 13.760' W
		Seashore Beach	XDF0255	2018 - present	38° 20.187' N	76° 24.499' W
Choptank River	CHOMH1	Point Lookout	XBG4203	2018 - present	38° 04.157' N	76° 19.707' W
		Harris Creek Profiler	XFG4618	2012 – present	38° 44.594' N	76° 18.203' W
		Harris Creek Downstream	XFG2810	2013 – present	38° 42.751' N	76° 19.008' W
Patapsco River	PATMH	Harris Creek Upstream	XFG6431	2013 – present	38° 46.389' N	76° 16.938' W
		Masonville Cove Pier	XIE4742	2013 – present	39° 14.680' N	76° 35.831' W
		Aquarium West	XIE7135	2016 – present	39° 17.126' N	76° 36.526' W
		Aquarium East – Surface	XIE7136	2016 – present	39° 17.128' N	76° 36.477' W
Patuxent River	PAXTF	Aquarium West - Bottom	XIE7136	2016 – present	39° 17.128' N	76° 36.477' W
		Jug Bay	PXT0455	2003 – present	38° 46.877' N	76° 42.822' W
	WBRTF	Mataponi	MTI0015	2003 – present	38° 44.599' N	76° 42.446' W
Potomac River	POTOH	Iron Pot Landing	WXT0013	2003 – present	38° 47.760' N	76° 43.248' W
	POTMH	Mallows Bay Buoy	XDA8236	2018 – present	38° 28.217' N	77° 16.366' W
Wicomico River	WICMH	St. George's Creek	XBF7904	2006 – present	38° 07.866' N	76° 29.604' W
		Little Monie	LMN0028	2006 – present	38° 12.513' N	76° 48.276' W

**Table 4.** 2019 Water quality mapping calibration stations.

Station Name	Waterbody	LAT (NAD83)	LONG (NAD83)	ConMon Station
XDF6533	CB4MH South	38° 26.502' N	76° 26.718' W	
XDG5922	CB4MH South	38° 25.888' N	76° 17.790' W	YES
XEE3691	CB4MH South	38° 33.583' N	76° 30.924' W	YES
XEF4689	CB4MH South	38° 34.578' N	76° 21.114' W	
XFE1386	CB4MH South	38° 41.304' N	76° 31.350' W	
XFE5373	CB4MH North	38° 45.276' N	76° 32.694' W	
XFF2293	CB4MH North	38° 42.219' N	76° 20.718' W	YES
XGF1167	CB4MH North	38° 51.132' N	76° 23.214' W	
XGF5025	CB4MH North	38° 55.005' N	76° 27.503' W	YES
XGF7480	CB4MH North	38° 57.420' N	76° 22.026' W	
XBF7495	CB5MH	38° 07.410' N	76° 20.586' W	
XCG8862	CB5MH	38° 18.804' N	76° 13.760' W	YES
XCH2613	CB5MH	38° 12.618' N	76° 08.574.' W	
XDG2324	CB5MH	38° 22.290' N	76° 17.592' W	
XBG4203	CB5MH	38° 04.157' N	76° 19.707' W	YES

Multiple surveys are required to map larger water bodies. Central CB4MH and CB5MH, Eastern CB5MH, Northern CB4MH, and Southern CB4MH results will be combined to create water quality parameter spatial maps for each of the months sampled. Western CB5MH, conducted in St Jerome Creek and Southward to Point Lookout, will be mapped separately.

Maryland DNR staff will be responsible for maintaining all continuous monitoring sites and will conduct all water quality mapping cruises.



**Figure 1.** Map of 2019 continuous monitoring stations and water quality mapping systems, with progress of assessment. (Includes four sites in Maryland’s Coastal Bays that are not covered in this QAPP.) NOTE: The Chesapeake Bay Program and the Maryland Department of the Environment gave approval for discontinuing assessment of C&DOH after one year because the segment met its SAV acreage goal in 2015.

## 2. METHODS AND PERFORMANCE MEASURES

The Chesapeake Bay Shallow Water Quality Monitoring Program measures a number of physical and chemical parameters that are indicative of the Bay's eutrophication problem.

Several "natural" properties such as salinity and temperature in the water column provide important information for interpretation of water quality indicators. For example, water clarity criteria differ based on salinity regime.

Tables 5 and 6 summarize Quality Control checks utilized in the Shallow Water Monitoring Program.

Tables 7 (Continuous Monitoring) and 8 (Water Quality Mapping) list parameters measured *in situ* along with resolution, range, accuracy and equipment used.

Table 9 lists the parameters measured in the laboratory (from grab samples taken at calibration stations), their detection limits, methods references, and holding times and conditions.

**Table 5:** *In situ* monitor performance checks and acceptance criteria.

	Performance Checks	Acceptance Criteria
Precision	Comparison of readings from deployed sonde against new sonde and discrete sonde when switching (Continuous Monitoring only).	See Table 11
Bias	Post-deployment calibration Fluorescence color blank	See Table 11
Accuracy	Pre-deployment calibration	
Representativeness	Daily checks of real-time data. Auto-notification of problems. Visual inspection to reject spikes	
Comparability	Use identical YSI equipment at all sites.	
Completeness	Data verification checks	Percentage of accepted data values.
Sensitivity	Manufacturer's specifications for each probe type.	See Appendix 1

**Table 6:** Discrete sample performance checks and acceptance criteria.

	Performance Checks	Acceptance Criteria
Precision	Intra-lab: replicate 1/10 samples. Inter-lab: quarterly Chesapeake Bay split samples.	Replicate control limits (For each parameter)
Bias and Accuracy	Analyze SRMs with each run. Spike 1/20 samples. Semi-annual blind audit sample. Semi-annual USGS ref. samples. Field blanks for nutrient samples.	% Recover of SRM % Recovery of Spikes ± 3 std. dev. of mean ± 3 pseudo-σ of mean
Comparability	Use standard procedures for collecting and analyzing samples.	
Completeness	Number of reported values vs. number of samples submitted for analysis.	
Sensitivity	MDL calculated for each parameter according to 40 CFR, Part 136B.	See Table 9

**Table 7.** Continuous monitoring *in situ* water column parameters.

Parameter (Units)	Resolution	Range	Accuracy	Equipment
Specific Conductance (mS/cm=mmhos/cm)	0.001 to 0.1 mS/cm (range-dependent)	0 to 100 mS/cm	±0.5% of reading + 0.001 mS/cm	YSI 6600 6560 probe
	0.0001 to 0.01 mS/cm (range-dependent)	0 to 200 mS/cm	0-100 mS/cm: ±0.5% of reading or 0.001 mS/cm, whichever is greater; 100-200 mS/cm: ±1% of reading	YSI EXO® 599870 probe-
	0.0001 to 0.01 mS/cm (range-dependent)	0 to 100 mS/cm	±1% of reading or 0.002 mS/cm, whichever is greater	YSI EXO® 599827 probe-
Dissolved Oxygen (mg/L)	0.01 mg/L	0 to 50 mg/L	0 to 20 mg/L: ±1% of reading or 0.1 mg/L, whichever is greater; 20 to 50 mg/L: ±15% of reading	YSI 6600 6150 ROX probe+
	0.01 mg/L	0 to 50 mg/L	0 to 20 mg/L: ±1% of reading or 0.1 mg/L, whichever is greater; 20 to 50 mg/L: ±5% of reading	YSI EXO® 599100-01 probe
Dissolved Oxygen (% saturation)	0.1 %	0 to 500 %	0 to 200%: ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%: ±15% of reading	YSI 6600 6150 ROX probe+
	0.1 %	0 to 500 %	0 to 200%: ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%: ±5% of reading	YSI EXO® 599100-01 probe
Fluorescence	0.1 RFU	0 to 100 RFU	NA	YSI 6600 6025 probe
	0.01 RFU	0 to 100 RFU	NA	YSI EXO® probes used: 599102-01, 599103-01; both have the same specifications
Total Chlorophyll	0.1 µg/L	EM 470 nm; EX 650 to 700 nm; ~0 to 400 µg/l	NA	YSI 6600 6025 probe
	0.01 µg/L	~0 to 400 µg/l	NA	YSI EXO® probes used: 599102-01, 599103-01; both have the same specifications
Photosynthetic Active Radiation (PAR)	See Appendix 4	See Appendix 4	See Appendix 4	LI-192SA and LI-190SA
pH (pH units)	0.01units	0 to 14 units	±0.2 units	YSI 6600 probes used: 6561, 6561FG and 6579 (hemispherical); all have the same specifications
	0.01units	0 to 14 units	±0.1 pH units within ±10°C of calibration temperature; ±0.2 pH units for entire temp range	YSI EXO® 599702 probe

Salinity (ppt)	0.01 ppt	0 to 70 ppt	±1% of reading or 0.1 ppt, whichever is greater	YSI 6600 6560 probe
	0.01 ppt	0 to 70 ppt	±1% of reading or 0.1 ppt, whichever is greater	YSI EXO <sup>®</sup> 599870 probe <sup>-</sup>
	0.01 ppt	0 to 70 ppt	±2% of reading or 0.2 ppt, whichever is greater	YSI EXO <sup>®</sup> 599827 probe <sup>-</sup>
Secchi depth (m)	NA	0.1 m (lower limit)	NA	Secchi disk (20 cm or 25.2 cm)
Turbidity (NTU/FNU) <sup>&amp;</sup>	0.1 NTU	0 to 1000 NTU	±2% of reading or 0.3 NTU, whichever is greater	YSI 6600 6136 probe <sup>*</sup>
	0-999 FNU: 0.01 FNU; 1000-4000 FNU: 0.1 FNU	0 to 4000 FNU	0-999 FNU: 0.3 FNU or ±2% of reading, whichever is greater; 1000-4000 FNU: ±5% of reading	YSI EXO <sup>®</sup> 599101-01 probe
Water Temperature (°C)	0.01°C	-5 to 50 °C	±0.15 °C	YSI 6600 6560 probe
	0.001°C	-5 to 50 °C	-5 to 35°C: ±0.01°C 35 to 50°C: ±0.05°C	YSI EXO <sup>®</sup> 599870 probe <sup>-</sup>
	0.001°C	-5 to 50 °C	±0.2°C	YSI EXO <sup>®</sup> 599827 probe <sup>-</sup>
Depth (shallow sensor)	0.001 m	0 to 9.1 m	+0.018 m	YSI 6600 <sup>^</sup>
	0.001 m	0 to 10 m	±0.04% FS (±0.004 m)	YSI EXO <sup>®</sup> <sup>^</sup>
Depth (medium sensor)	0.001 m	0 to 61 m	+0.12 m	YSI 6600 <sup>^</sup>
	0.001 m	0 to 100 m	±0.04% FS (±0.04 m)	YSI EXO <sup>®</sup> <sup>^</sup>
Blue-Green Algae PE <sup>**</sup> (Marine and Estuarine waters)	1cell/mL or 0.1 RFU	~ 0 to 200,000 cell/mL or 0 to 100 RFU	NA	YSI 6600 6132 probe
	0.01 µg/L or 0.01 RFU	0 to 280 µg/L or 0 to 100 RFU	NA	YSI EXO <sup>®</sup> 599103-01 probe

+ Between 1998 and 2009, the older model 6562 rapid pulse dissolved oxygen probe was used in some instruments. Beginning in 2010, the 6150 ROX optical dissolved oxygen probe was used exclusively.

\* Between 1998 and 2004 the older model 6026 turbidity probe was in use in some instruments. Beginning in 2005, the 6136 turbidity probe was used exclusively.

<sup>^</sup> The depth sensors are built into the YSI 6600 and EXO instruments, and do not have an individual probe model number. Some instruments in the DNR inventory do not have depth sensors.

<sup>®</sup> Beginning in 2014, YSI EXO instruments were used at select sites.

<sup>&</sup> YSI 6600 instruments output turbidity measurements in Nephelometric Turbidity Units (NTU). YSI EXO instruments output turbidity measurements in Formazin Nephelometric Units (FNU). 1 NTU = 1 FNU and the different unit names is due to different methods used to measure turbidity.

<sup>\*\*</sup> During 2019 YSI EXO2 sondes with Blue-Green Algal PE probes will be deployed adjacent to the National Aquarium in Baltimore.

<sup>-</sup> Beginning in 2016, some YSI EXO instruments were equipped with wiped conductivity/temperature probes (599827) to improve data integrity.

**Table 8.** Water Quality Mapping *in situ* water column parameters.

Parameter (Units)	Resolution	Range	Accuracy	Equipment
Specific Conductance (mS/cm=mmhos/cm)	0.001 to 0.1 mS/cm (range-dependent)	0 to 100 mS/cm	±0.5% of reading + 0.001 mS/cm	YSI 6600 6560 probe
Dissolved Oxygen (% saturation)	0.1 %	0 to 500 %	0 to 200%: ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%: ±15% of reading	YSI 6600 6150 ROX probe+
Dissolved Oxygen (mg/L)	0.01 mg/L	0 to 50 mg/L	0 to 20 mg/L: ±1% of reading or 0.1 mg/L, whichever is greater; 20 to 50 mg/L: ±15% of reading	YSI 6600 6150 ROX probe+
Fluorescence	0.1RFU	0 to 100 RFU	NA	YSI 6600 6025 probe
Total Chlorophyll	0.1 µg/L Chl	EM 470 nm; EX 650 to 700 nm; 0 to 400 µg/l	NA	YSI 6600 6025 probe
Photosynthetic Active Radiation (PAR)	See Appendix 4	See Appendix 4	See Appendix 4	LI-192SA and LI-190SA
pH (pH units)	0.01units	0 to 14 units	±0.2 units	YSI 6600 6561 probe
Salinity (ppt)	0.01 ppt	0 to 70 ppt	±1% of reading or 0.1 ppt, whichever is greater	YSI 6600 6560 probe
Secchi depth (m)	NA	0.1 m (lower limit)	NA	Secchi disk (20 cm or 25.2 cm)
Turbidity (NTU)	0.1 NTU	0 to 1000 NTU	±2% of reading or 0.3 NTU, whichever is greater	YSI 6600 6136 probe*
Water Temperature (°C)	0.01°C	-5 to 50 °C	±0.15 °C	YSI 6600 6560 probe
Depth	0.001 m	0 to 9 m	±0.02 m	Garmin GPSmap 168 sounder or Raymarine A70D Plotter/Sounder or GPSU and Loggui software (fR/V Kerhin)
Position	15 m	NA	±5 m; ±2-3 m with Northstar	Garmin GPSmap 168 sounder or Raymarine A70D Plotter/Sounder or GPSU and Loggui software (R/V Kerhin) or Northstar 952X Differential GPS (R/V Rachel Carson)

+ Between 1998 and 2009, the older model 6562 rapid pulse dissolved oxygen probe was used for water quality mapping surveys. Beginning in 2010, the 6150 ROX optical dissolved oxygen probe was used exclusively.

\* Between 1998 and 2004 the older model 6026 turbidity probe was in use in some instruments. Beginning in 2005, the 6136 turbidity probe was used exclusively.

**Sources for Tables 7 and 8:**

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**Table 9.** Shallow Water Monitoring Program Grab Sample Water Column Parameters, Detection Limits, Methods, References, and Holding Times and Conditions.

Parameter (Units)	Detection Limit (or Range)	Method Reference	Holding Time and Condition
Orthophosphate (mg/L as P)	0.0034 mg/L	EPA method 365.1 (EPA 1993) Aquakem 250	Freezing-28 d
Total Diss. Phosphorus (mg/L as P)	0.0015 mg/L	Aquakem 250 and AutoAnalyzer II; Valderrama (1981), Alkaline persulfate digestion	Freezing-28 d
Particulate Phosphorus (mg/L as P)	0.0021 mg/L	Aspila et al. (1976) Aquakem 250	Freezing-28 d
Particulate Inorganic Phosphorus (mg/L as P)	0.0021 mg/L	Aspila et al. (1976) Aquakem 250	Freezing-28 d
Nitrite (mg/L as N)	0.0007 mg/L	EPA method 353.2 (EPA 1993) Aquakem 250	Freezing-28 d
Nitrite + Nitrate (mg/L as N)	0.0007 mg/L	EPA method 353.2 (EPA 1993) and enzymatic nitrate method. Aquakem 250	Freezing-28 d
Ammonium (mg/L as N)	0.013 mg/L	EPA method 350.1 (EPA 1993) Aquakem 250	Freezing-28 d
Total Dissolved Nitrogen (mg/L as N)	0.05 mg/L	Aquakem 250 and AutoAnalyzer II; D'Elia et al. (1977) Valderrama (1981) , Alkaline persulfate digestion	Freezing-28 d
Dissolved Organic Carbon (mg/L as C)	0.16 mg/L	Sugimura and Suzuki (1988)	Freezing-28 d
Particulate Nitrogen (mg/L as N)	0.0263 mg/L	EPA method 440.0 (EPA 1997)	Freezing-28 d
Particulate Carbon (mg/L as C)	0.0633 mg/L	EPA method 440.0 (EPA 1997)	Freezing-28 d
Total Suspended Solids (mg/L)	2.4 mg/L	Standard Method (APHA 19th or 20th edition) Method 2540 D	Freezing-28 d
Volatile Suspended Solids (mg/L)	0.9 mg/L	Standard Method (APHA 19th or 20th edition) Method 2540 D	Freezing-28 d
Chlorophyll a (µg/L)	0.62 µg/L	Standard Methods 10200H, 21st Ed.	Freezing-28 d
Pheophytin a (µg/L)	0.74 µg/L	Standard Methods 10200H, 21st Ed.	Freezing-28 d
Carbonate Alkalinity	0.75 mg/L	Total Organic Carbon Analyzer Model TOC-5000A: Instruction Manual	Refrigeration-28 d

References for Table 9:

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American Public Health Association (APHA), *Standard Methods for the Examination of Water and Wastewater*, [4500-NH3 G. Automated Phenate Method](#), 20<sup>th</sup> Edition, 1998.

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- Zimmerman, C. F., C. W. Keefe, AND J. Bashe. Method 440.0 [Determination of Carbon and Nitrogen in Sediments and Particulates of Estuarine/Coastal Waters Using Elemental Analysis.](#) U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/009, 1997.

### 3. FIELD MEASUREMENTS AND SAMPLING

#### 3.1. Continuous Monitoring

Each continuous monitoring station is equipped with a YSI 6600 or YSI EXO sonde. Beginning in 2004, all YSI 6600 data sondes were equipped with Extended Deployment Systems (EDS). The EDS has a wiper system that allows the continuous monitoring sondes to be deployed for longer periods of time without suffering a degradation of data quality as a result of biofouling. Starting in 2007, some instruments were converted from EDS to the V2 model, which supports four optical ports. Between 2009 and 2015, all sondes used for Continuous Monitoring utilized V2 technology. In addition to chlorophyll fluorescence and turbidity, the additional two optical ports may be configured for 6150 optical dissolved oxygen and blue-green algal probes. Beginning in 2014, new EXO model instruments were purchased to replace older YSI 6600 models as the SWM Program began to transition to this newer technology. All EXO sondes have a central wiper system and a copper-alloy sensor guard which will further reduce biofouling and associated degradation of data quality. Each continuous monitoring sonde records nine water quality parameters every 15 minutes. The nine water quality parameters measured continuously are water temperature, specific conductance, salinity (calculated from specific conductance and temperature), dissolved oxygen, turbidity (NTU/FNU), fluorescence and total chlorophyll (estimated from fluorescence), pH, and depth. EXO sondes that will be deployed at sites on the Patapsco, Potomac, and Wicomico Rivers, Upper Central Chesapeake Bay (CB3MH), Middle Central Chesapeake Bay (CB4MH), and Lower Central Chesapeake Bay (CB5MH) may also be configured with total algal sensors that measure both chlorophyll *a* and blue-green algal concentrations in µg/L and RFU.

Since 2008, sonde sensors have been wrapped in copper tape (2" diameter; 3.5 mm thickness) to inhibit biological growth. Starting in 2010, several sondes have also been equipped with anti-fouling probes and probe guards that utilize copper housings to further reduce biological growth on sensors. Continuous monitoring sondes are positioned in the water column in either a floating configuration that suspends the sonde at some distance below the surface (usually 1-meter), or in an anchored configuration that fixes the sonde at some distance above the bottom (usually 0.3m or 0.5m above bottom). The sonde is positioned in the water column in either a floating configuration or a fixed configuration depending on the geographic area being monitored, the monitoring goals for that segment, and the total water depth at a particular site. One exception to this configuration is the water quality vertical profiler, which will be deployed in Harris Creek. The vertical profiler lowers a YSI 6600 sonde into the water column and takes a water quality reading every 0.5 meters.

Continuous monitoring 6600 sondes in a floating configuration are suspended from a float inside of a 4-inch diameter PVC pipe with 2-inch diameter holes drilled every 4 inches below the waterline to allow for water exchange. There are three floating configurations for EXO sondes. The first configuration suspends the sonde from a float inside a 6-inch PVC tube perforated with 2-inch diameter holes to allow for water exchange. The second configuration suspends a 4-inch diameter by 3-foot PVC tube with 2-inch diameter holes with sonde inside utilizing a large orange inflatable buoy. The third configuration suspends the sonde from a small, floating buoy. All sonde tubes are painted below the water line with black antifouling paint (Petit Trinidad™ SR or similar). 6600 sondes in a fixed configuration are also housed inside a perforated 4-inch diameter PVC pipe, and a bolt is used to hold the negatively buoyant sonde at a fixed depth above the sediment bottom. EXO sondes in a fixed configuration are either housed in a 4-inch diameter by 4-foot long PVC tube perforated with 2-inch diameter holes, or inside a crabpot-like structure that rests on the bottom and suspends the instrument 0.3m off bottom in a horizontal PVC tube tethered to a pier with a cable. At selected sites, telemetry is used to transmit the data in near real-time to DNR's Eyes on the Bay web site (<http://www.eyesonthebay.net>). The telemetry system is comprised of a field component located at each sampling site and an office component located at the central DNR building in Annapolis. The field component consists of either a YSI 6200 data logger, a

Campbell Scientific CR1000 data logger, or a NexSens 3100-iSIC data logger housed in a weather resistant fiberglass-reinforced polyester enclosure. Each unit also contains a battery, solar panel and a digital CDMA modem. Every hour, the computer server located at DNR contacts the data logger located at each telemetered sampling site via TCP/IP communications and then uploads, archives, and updates the data display on the Eyes on the Bay web site. These data are available immediately on the Internet, allowing the general public to view near real-time water quality data. Details of the steps for installing, calibrating, deploying, and retrieving the YSI instruments are provided in Appendix 2.

In addition to the parameters measured by the sondes, Secchi depth and light attenuation (Appendix 4) are measured bi-weekly from April to October, and grab samples are taken and filtered on-site or immediately after returning to the lab. See Appendix 7 for a description of the filtering procedures. The processed samples are sent to the Nutrient Analytical Services Laboratory (NASL) at the Chesapeake Biological Laboratory for analysis. These results will be used to analyze relationships between the water quality parameters measured by each continuous monitor and nutrient components. Some of the lab data are also used to check the YSI data for accuracy. The following parameters are analyzed at NASL: ammonium, total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, particulate phosphorus, total dissolved phosphorus, orthophosphate, particulate carbon, total suspended solids, volatile suspended solids, particulate inorganic phosphorus, alkalinity, chlorophyll *a*, and pheophytin. Samples from two Continuous Monitoring sites in Harris Creek will be analyzed for all of these parameters, while samples from an additional five sites associated with the NERR System, as well as one site associated with a proposed National Marine Sanctuary, will be analyzed for a subset of nutrients (TSS, VSS, NH<sub>4</sub>, PO<sub>4</sub>, NO<sub>2</sub>, NO<sub>23</sub>, TN, TP), pheophytin, and chlorophyll *a*. Samples from three sites in Harris Creek will also be analyzed for alkalinity. Samples from the remaining sites, with the exception of two sites adjacent to the National Aquarium in Baltimore will be analyzed for chlorophyll *a*, pheophytin, and TSS only. No samples will be collected by DNR at the National Aquarium sites. At those sites, however, the National Aquarium in Baltimore collects weekly samples that are analyzed for total dissolved nitrogen, total dissolved phosphorus, and Biological Oxygen Demand (BOD).

### **3.2 Water Quality Mapping**

Water quality mapping is conducted using a system deployed on a small or large boat. The system is comprised of geospatial equipment and water quality probes that measure water quality parameters from a flow-through stream of water collected near the water's surface. The eight water quality parameters measured are: water temperature, specific conductance, salinity (calculated from specific conductance and temperature) dissolved oxygen, turbidity (NTU), fluorescence, total chlorophyll (estimated from fluorescence) and pH.

On the smaller vessels, water is pumped through a ram (pipe), across the sensors, and then discharged overboard. The water quality mapping system includes a Raymarine A70D or a Garmin model GPSMAP168 Sounder chartplotting receiver and depth-finder, a YSI 6600 sonde with a flow-through chamber, a YSI 6150 ROX dissolved oxygen probe, a 6561 pH probe, a YSI 6560 conductivity/temperature probe, a 6136 turbidity probe, and a 6025 chlorophyll probe. The sonde transmits data from the sensors to a ruggedized computer. Each water quality datum is associated with a date, time, water depth, and GPS Latitude and Longitude coordinates (NAD83).

On the larger vessel, the setup is similar except no ruggedized computer is used and the YSI logs the water quality data internally as water from the thru hull of the boat is pumped into the flow cell and across the sensors. GPSU and Loggui software is used to log position from the wheel house of the larger vessel. This data is then merged using the time stamps of the YSI water quality data and GPS software data.

Water quality mapping allows data to be collected rapidly (approximately every four seconds) while the boat is traveling at speeds of up to 25 knots. Typical large vessel cruising speed was 28 km/hr (15 kts). Measurements were made approximately every four seconds, or 17 meters (56 feet). The water quality mapping system for the smaller vessels are compact and can be fit onto a small boat, allowing sampling in shallow water and the ability to map an entire small tributary, such as the Severn River, in less than a day. The distance between samples depends on vessel speed; generally at least one observation is collected every 30 meters (~100 feet). Details of the steps for calibrating, initializing and running the water quality mapping system are provided in Appendix 3.

The water quality mapping system samples water at depths of approximately 0.5m below the surface. At calibration stations, grab samples also are collected at 0.5m depth and filtered on site. See Appendix 3 for a description of the filtering procedures. Processed samples are sent to the Chesapeake Biological Laboratory Nutrient Analytical Services Laboratory (NASL). Parameters analyzed at NASL are chlorophyll *a*, pheophytin, and TSS. In addition, Secchi depth and photosynthetic active radiation (PAR) measurements are taken at calibration stations to calculate light attenuation ( $K_d$ ) (Appendix 4). The calibration station locations are selected to:

- 1) sample the greatest possible range of water quality conditions found during each cruise;
- 2) sample a broad spatial area;
- 3) overlap with long-term fixed monitoring and continuous monitoring stations. For more details on equipment and sampling design, see [Boynton et al. 2002](#), Rohland et al. 2002, and [Bailey et al. 2008](#).

#### 4. LABORATORY ANALYSIS

All laboratory-measured parameters are analyzed at the University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory (CBL), Nutrient Analytical Services Laboratory (NASL). For details, refer to Appendix VII in the Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program Chemical and Physical Properties Component for the Period July 1, 2019 - June 30, 2020 (Cole and Parham 2019).

Appendix VII is an aggregation of NASL methods documents. Table 10 lists the documents in Appendix VII.

**Table 10.** NASL methods

Water Column Chemistry	Method	Revised
Ammonium Method	<i>Standard Operating Procedure for Determination of Dissolved Inorganic Ammonium (NH<sub>4</sub>) in Fresh/Estuarine/Coastal Waters (References Standard Methods 4500-NH3 G-1997)</i>	1-May-2019
Cadmium Nitrate Method	<i>Standard Operating Procedure for Determination of Dissolved Inorganic Nitrate plus Nitrite (NO<sub>3</sub>+NO<sub>2</sub>) in Fresh/Estuarine/Coastal Waters Using Cadmium Reduction (References EPA 353.2)</i>	1-May-2019
Enzyme Catalyzed Nitrate Method	<i>Standard Operating Procedure for Determination of Dissolved Inorganic Nitrate plus Nitrite (NO<sub>3</sub>+NO<sub>2</sub>) in Fresh/Estuarine/Coastal Waters Using Enzyme Catalyzed Reduction (References EPA 353.2, Standard Methods #4500-N C, 4500-NO3 F)</i>	1-May-2019
Inorganic Carbon Method	<i>Standard Operating Procedure for Determination of Aqueous Inorganic Carbon and calculated Carbonate Alkalinity in waters of Fresh/Estuarine/Coastal Waters. (References: ASTM D7573-09)</i>	1-May-2019
Nitrite Method	<i>Standard Operating Procedure for Determination of Dissolved Inorganic Nitrite (NO<sub>2</sub>) in Fresh/Estuarine/Coastal Waters (References EPA 353.2)</i>	1-May-2019

Orthophosphate Method	<i>Standard Operating Procedure for Determination of Dissolved Inorganic Orthophosphate (PO<sub>4</sub>) in Fresh/Estuarine/Coastal Waters (References EPA 365.1)</i>	1-May-2019
Silicate Method	<i>Determination of Silicate from Fresh, Estuarine, and Coastal Waters Using the Molybdosilicate Method (Reference Method: EPA Method 366.0)</i>	1-May-2019
Total Dissolved Nitrogen Enzyme Catalyzed Nitrate Method	<i>Standard Operating Procedure for Determination of Total Dissolved Nitrogen (TDN) and Total Nitrogen (TN) in Fresh/Estuarine/Coastal Waters Using Alkaline Persulfate Digestion of Nitrogen to Nitrate and Measured Using Enzyme Catalyzed Reduction (References EPA 353.2, Standard Methods #4500-N C, 4500-NO3 F)</i>	1-May-2019
Total Dissolved Nitrogen Cadmium Nitrate Method	<i>Standard Operating Procedure for Determination of Total Dissolved Nitrogen (TDN) and Total Nitrogen (TN) in Fresh/Estuarine/Coastal Waters Using Alkaline Persulfate Digestion of Nitrogen to Nitrate and Measured Using Cadmium Reduction (References EPA 353.2, Standard Methods #4500-N C, 4500-NO3 F)</i>	1-May-2019
Total Dissolved Phosphorus Discrete Photometric Analyzer Method	<i>Standard Operating Procedure for Determination of Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) in Fresh/Estuarine/Coastal Waters Using Alkaline Persulfate Digestion of Phosphorus to Orthophosphate (PO<sub>4</sub>) with Colorimetric Analysis by Random Access Discrete Photometric Analyzer (References Standard Methods #4500-P.B.5, #4500 P.E, and EPA Method 365.1)</i>	1-May-2019
Total Dissolved Phosphorus Auto Analyzer II System Method	<i>Standard Operating Procedure for Determination of Total Dissolved Phosphorus (TDP) and Total Phosphorus (TP) in Fresh/Estuarine/Coastal Waters Using Alkaline Persulfate Digestion of Phosphorus to Orthophosphate (PO<sub>4</sub>) (References Standard Methods #4500-P.B.5, #4500 P.E, and EPA Method 365.1)</i>	1-May-2019
Total and Dissolved Organic and Inorganic Carbon Method	<i>Standard Operating Procedure for Determination of Dissolved Organic Carbon/Non-Purgeable Organic Carbon (DOC/NPOC), and Total Organic Carbon (TOC) in Fresh/Estuarine/Coastal Waters using High Temperature Combustion and Infrared Detection. (References: SM5310B)</i>	1-May-2019
Particulate Carbon and Nitrogen Method	<i>Standard Operating Procedure for Determination of Carbon and Nitrogen in Particulates and Sediments of Fresh/Estuarine/Coastal Waters, Plant and Animal Tissue, and Soils Using Elemental Analysis. (Reference Method: EPA 440.0)</i>	1-May-2019
Particulate Phosphorus Method	<i>Determination of Total Particulate Phosphorus (TPP) and Particulate Inorganic Phosphorus (PIP) in Fresh/Estuarine/Coastal Waters (Reference Method: EPA 365.1, Rev. 2.0)</i>	8-April-2019
Total Suspended Solids and Total Volatile Solids Methods	<i>Determination of Total Suspended Solids (TSS) and Total Volatile Solids (TVS) in Waters of Fresh/Estuarine/Coastal Waters. (Reference Method: EPA Method 160.2 and Standard Methods 208 E.)</i>	1-May-2019
Chlorophyll Spectrophotometric Method	<i>Standard Operating Procedure for Spectrophotometric Determination of Chlorophyll <math>\alpha</math> in waters and sediments of Fresh/Estuarine/Coastal Areas. (References: EPA 446.0, SM10200H.2)</i>	1-May-2019

Current versions of NASL methods documents are maintained on-line by NASL and may be accessed at the following URL: <<http://www.umces.edu/nutrient-analytical-services-laboratory>>.

To ensure that samples are processed within the holding times, samples are packed in ice immediately after filtering and taken to the field office and stored in a freezer, with the exception of samples for alkalinity which are kept chilled but not frozen. The frozen or refrigerated samples are packed in ice and driven to NASL weekly to be processed. NASL staff process and analyze the samples within the holding time periods established under the specific parameter method reference and listed in Table 9.

## 5. DATA MANAGEMENT, VERIFICATION AND DOCUMENTATION

### 5.1 Continuous Monitoring

At most continuous monitoring stations, sondes are retrieved, calibrated and replaced every two to four weeks from April to October. One deep water station at the Gooses Reef will be serviced on a monthly basis. Two sites in Harris Creek, two sites adjacent to the National Aquarium in Baltimore, the Masonville Cove site in the Patapsco River, the Mallows Bay site in the Potomac River, the Gooses Reef site in CB4MH, and the three National Estuarine Research Reserve (NERR) sites on the upper Patuxent and one NERR site at Otter Point Creek on the Bush River are maintained year round unless severe icing during the winter prohibits deployment. For these stations, continuous monitoring sondes are generally retrieved, calibrated, and replaced monthly between November and March.

In the field, before a continuous monitoring sonde is replaced, a three-way *in situ* match-up is conducted. The new (freshly calibrated) sonde is suspended next to the PVC tube, at the same depth of the old (deployed) sonde in the tube. For bottom mounted sondes, an instrument is lowered to the bottom and then brought up 0.3-0.5m off the bottom. A discrete check sonde (either a Hydrolab or similar YSI instrument) is also suspended in the water at the same depth. A synchronized reading is taken at the next sonde-data-storage 15-minute interval with the old, new and check sondes. A second synchronized reading is taken at the following 15-minute interval with just the old and the new sondes. After two synchronized readings have been taken, a water column profile is conducted using the discrete sonde (Appendix 2). After conducting the water column profile, the old sonde is removed from the PVC tube and the tube is cleaned with a brush (Webster™ duster or similar) to remove biofouling and clear debris from inside and outside of the tube as well as from any telemetry cables or the floating mechanism (if applicable). Once everything has been cleaned, the new sonde is placed in the PVC tube.

The three-way comparison assures that the new and old sondes are both reading each parameter within a certain tolerance (Table 11). The check sonde allows for notation on whether or not the parameters are fluctuating or stable (Appendix 2).

The retrieved sonde is returned to the field office and placed in 100% air saturated water. The sonde must rest in the air saturated water for approximately 20 minutes to equilibrate to temperature and pressure (often the sonde is left overnight). After equilibration, a dissolved oxygen check is conducted as outlined in Appendix 2, the data are uploaded to a personal computer using YSI's Ecowatch™ or KOR-EXO™ software, and the remaining post-calibration procedures are conducted as outlined in Appendix 2.

After post-calibration procedures have been completed, data are subjected to a series of quality assurance (QA) and quality control (QC) checks to ensure that the data are not erroneous and that they are within the range of the sensor instrumentation (Appendix 1). Data from the three-way *in situ* match-up are first used to determine if a specific probe has drifted outside of an acceptable range (Table 11). Data may be rejected during the QA/QC checks when post-calibration drift exceeds the limits stated in Table 11 in both the post-calibration and the *in situ* comparables, or when data are clearly associated with probe failures. Section 5.3 describes the data management procedures common to the continuous monitoring and water quality mapping projects.

Parameter	Value
Chlorophyll	±5 % of true value or 5.0 µg/L (whichever is greater)
Dissolved Oxygen	±0.5 mg/L
pH	±0.2 pH units
Specific Conductance	±5 % of true value
Turbidity	±5 % of true value or 5.0 NTU (whichever is greater)
Water Temperature	±0.2 °C

Data from telemetered stations are examined daily by DNR staff. Automated programs also alert DNR staff when equipment malfunctions and probe failures may be occurring at real-time continuous monitoring stations. To ensure the quality of the data presented on the Eyes on the Bay (<http://www.eyesonthebay.net>) website, the real-time data is replaced with the QA/QC'd data generated after continuous monitoring sonde replacement. While every effort is made to ensure the quality of the data presented on Eyes on the Bay, DNR places disclaimers on the web site that state the following:

NOTE: Data from the current year are provisional and have not yet been through our rigorous Quality Assurance procedures.

At the end of the monitoring season, DNR staff conduct additional QA/QC procedures to discover problem data which may not have been detected earlier. Staff plot all of the data and then thoroughly research any outliers or other unusual values. For example, staff compare values outside the normal range to historic values and values elsewhere in the Bay, consider weather events, and consult with field staff regarding possible legitimate causes for those values. In cases where data are determined, by the Quality Assurance Officer, to be unreliable, the reason(s) values are determined to be unacceptable are documented with error codes and comments. Unreliable data are masked. No data are discarded. Only data considered reliable are published in reports or on the web.

Federal Geographic Data Commission compliant metadata records are routinely generated to describe the Continuous Monitoring project years, and are available on-line by using publication type 'Metadata' to search the Monitoring News and Reports page of the Eyes on the Bay website (<http://eyesonthebay.dnr.maryland.gov/eyesonthebay/stories.cfm>).

## **5.2 Water Quality Mapping**

Water Quality Mapping (WQM) is generally conducted once monthly in tributaries or Chesapeake Bay segments from April-October (Table 4, Figure 1). For tributaries with submerged aquatic vegetation restoration, specific monitoring projects, or in polyhaline segments, sampling may begin in March and end in November. In 2019, mapping surveys will be conducted in two Maryland Chesapeake Bay segments: CB4MH and CB5MH.

Cruise tracks vary depending on the system. In general, a square-wave pattern is followed by alternately sampling shallow shoreline areas and open, deeper waters while traveling up and downriver. Alternative cruise paths may be followed if tributary size or shape dictates otherwise. Cruise patterns are selected to obtain representative coverage of shallow water habitats and open waters so that segment-wide criteria can be assessed as accurately as possible. Navigational issues and placement of representative calibration sites also determine ultimate cruise tracks for WQM.

During data collection, field personnel keep a logbook and document any incidents or observations that may affect the integrity or interpretation of the data. Such observations may include perturbation of bottom sediments by the boat, observances of algal blooms or equipment malfunctions. After data collection, field personnel use the Shallow Water Monitoring QA/QC macro (See Appendix 13) to format data, discover and evaluate anomalous values, and to add error codes based on field notes and range checks where appropriate.

Original data files are named with a three-letter segment designation and an eight digit date (e.g. SEV05272005). Files that have been through the QAQC process are labeled with a "Q". After initial QA/QC by field personnel, data files are reviewed again by a data analyst. Scatter plots are generated to discover anomalous values. Data are also viewed using Geographic Information System (GIS) software tools, a procedure that can highlight positional errors and highlight errors that might only be observed within a geographical display.

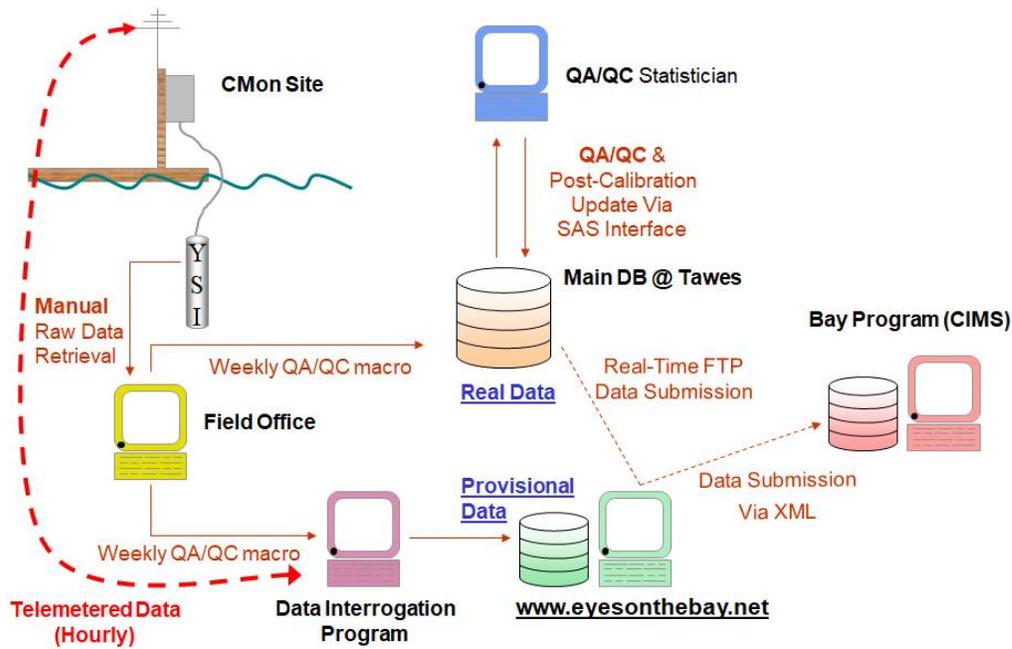
Preliminary maps of chlorophyll, dissolved oxygen, turbidity, water temperature and salinity are created and posted to the Water Quality Mapping Data page of the Eyes on the Bay website (<http://eyesonthebay.dnr.maryland.gov/sim/DataflowDataMenu.cfm>). Maps are generated using a default inverse distance weighted interpolation procedure. These maps give an overall perspective of water quality conditions and are meant for general reference, not for detailed analysis.

Federal Geographic Data Commission compliant metadata records are routinely generated to describe the Water Quality Mapping project years, and are available on-line by using publication type 'Metadata' to search the Monitoring News and Reports page of the Eyes on the Bay website (<http://eyesonthebay.dnr.maryland.gov/eyesonthebay/stories.cfm>).

### **5.3 Data Management**

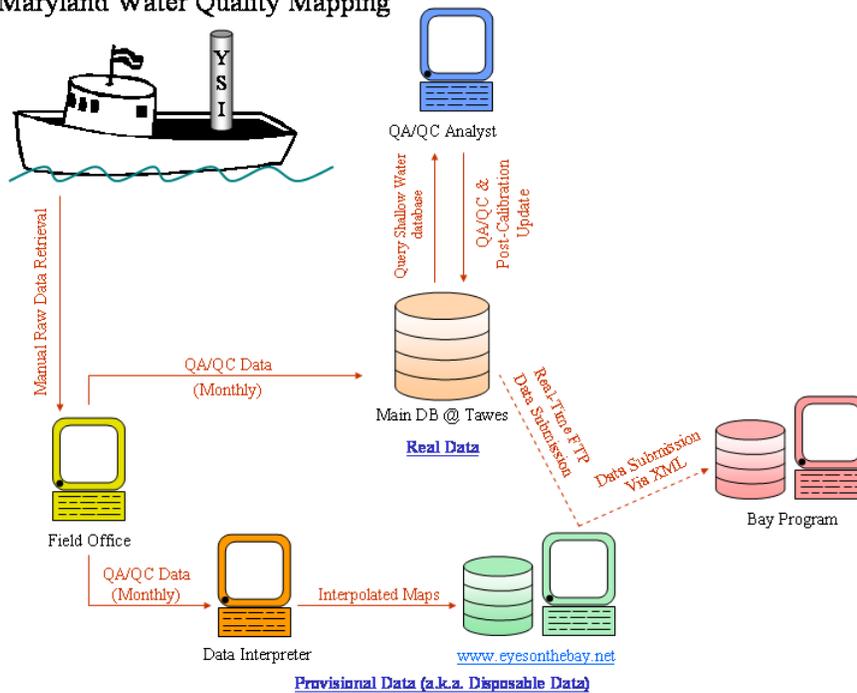
All shallow water monitoring data (continuous monitoring and water quality mapping) are maintained in a Shallow Water Monitoring database as part of Maryland DNR's Water Quality Monitoring Program. Data that are rejected during QA/QC checks are never deleted. Data determined to be unreliable are masked with an appropriate error code (see Appendix 11) rather than deleted. This ensures that all raw data are archived and available for future re-evaluation. Techniques and technologies may be developed which will enable utilization of data that have been previously rejected. After the data from a deployment have undergone QA/QC checks, the QA/QC'd data files are transferred to an internal network directory where they are inserted into DNR's Shallow Water Monitoring database. Redundant backup copies of all raw data and QA/QC'd data are also maintained.

Maryland Continuous Monitoring



**Figure 2.** Conceptual diagram of Continuous Monitoring data management components, including automated data submission from DNR to the Chesapeake Bay Program - Chesapeake Information Management System (CIMS).

Maryland Water Quality Mapping



**Figure 3.** Conceptual diagram of Water Quality Mapping data management components, including automated data submission from DNR to the Chesapeake Bay Program - Chesapeake Information Management System (CIMS).

## 5.4 Documentation and Records

Documentation and records maintained by the Continuous Monitoring project and the Water Quality Mapping project include: YSI Calibration and Post-Calibration Procedures (Appendix 5 and 6), Continuous Monitoring and Water Quality Mapping Filtering Methods (Appendix 7), Photosynthetic Active Radiation Protocol (Appendix 4), Continuous Monitoring Procedures (Appendix 2), Water Quality Mapping Procedures (Appendix 3), Continuous Monitoring Instrument Calibration and Comparison Tables and Calibration Log (Appendix 5), Continuous Monitoring Data Verification and Management Procedures (Appendix 12), Water Quality Mapping Data Verification and Management Procedures (Appendix 13) and the Log of Significant Changes (Appendix 14).

## 6. PROJECT QUALITY ASSURANCE/QUALITY CONTROL

*NOTE: On September 10, 2007, the deionized (DI) water generator used by Maryland DNR was upgraded from an in-line filter cartridge type, to a reverse osmosis/UV sterilization type. This apparatus is a Thermo Scientific Barnstead DIamond™ TII Water System. All manufacturer recommendations are followed regarding cartridge replacement and system sanitation. Refer to Thermo Scientific. 2007. Barnstead DIamond TII Type II Water System Operation Manual and Barnstead DIamond TII Type II Storage Reservoir Operation Manual. A log is kept at the front of the DI System Manual to document all changes and updates made to the system. Also, beginning in 2010, along with filtered samples for nutrient analysis, blank DI samples are sent to CBL to check for contamination of DI water used in filtering samples.*

An initial quality assurance (QA) and quality control (QC) check is performed by field staff, who inspect all data for outliers and mask outliers in the data set as deemed appropriate before reporting any data. Field staff also mask any data for parameters that did not post-calibrate within specifications. See Tables 7 and 8 in Section 2 and Table 11 in Section 5 for limits on accuracy and instrument drift. See Appendices 5 and 6 (YSI Calibration and Post-Calibration Procedures) and Appendices 12 and 13 (Continuous Monitoring and Water Quality Mapping Data Verification and Management Procedures) for a description of QA/QC and calibration procedures used by the field staff. Additional quality assurance and control is performed by members of DNR staff to identify any erroneous data missed in the initial QA/QC and compare current data to historical data.

### 6.1 Accuracy

The accuracy (closeness to the true value) of the collected data is controlled and assured by the proper use, calibration, and maintenance of both field and laboratory equipment for the measurement of physical and chemical parameters. All instruments are identified by a unique number, used as an index for documentation of calibration, repair, and preventive maintenance.

Daily quality control checks (including the running of blanks and standards) are used to control and assure laboratory accuracy. See Cole and Parham (2019; Appendix VII) for details on the frequency of running blanks and standards and for additional procedures for laboratory quality assurance and control.

Accuracy of laboratory results is also assessed through DNR's participation in the Chesapeake Bay Coordinated Split Sample Program (CSSP), a split sampling program in which the coordinated split samples are analyzed by five laboratories involved in Chesapeake Bay monitoring. CSSP was established in June 1989 to establish a measure of comparability between sampling and analytical operations for water quality monitoring throughout the Chesapeake Bay and its tributaries. DNR follows the protocols in the *Chesapeake Bay Coordinated Split Sample Program Implementation Guidelines* (EPA 1991) and

its revisions. Split samples are collected quarterly. Results are analyzed by appropriate statistical methods to determine if results differ significantly among labs. When a difference occurs, discussion begins regarding techniques and potential methods changes to resolve discrepancies through the Data Integrity Workgroup (DIWG – a Chesapeake Bay Program workgroup, formerly AMQAW - Analytical Methods and Quality Assurance Workgroup).

Additionally, CBL participates two times per year in the United States Geologic Survey (USGS) reference sample program and permits USGS to release the results to the Chesapeake Bay Program Quality Assurance Officer.

Procedures to control and assure the accuracy of field measurements involve the calibration of field instruments, the verification of these calibrations, equipment maintenance, and collection of filter blanks.

## **6.2 Precision**

Precision (repeatability) of the chemical analytical methods is determined and documented from duplicate analyses. The protocols for duplicate analyses in the laboratory are described in the Standard Operating Procedures for CBL, found in Appendix VII in the Quality Assurance Project Plan for the Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program Chemical and Physical Properties Component for the Period July 1, 2019 - June 30, 2020 (Cole and Parham 2019).

## **6.3 Data Review and Data Verification**

Data review and data verification ensure the quality assurance and quality control of data. These are discussed in Section 5 above.

## **6.4 Audits**

Performance audits for chemical analyses conducted at the University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory Nutrient Analytical Services Laboratory (NASL) are based on the results of samples distributed by the EPA Chesapeake Bay Program Blind Audit Program. These samples must fall within the 95% confidence interval for acceptance. If results fall outside this range, corrective actions for each parameter and measurement are taken. NASL prepares the blind audit samples for all participating laboratories and also analyzes some of those samples. For dissolved nitrogen and dissolved phosphorus, a laboratory quality assurance officer determines the concentrations in the ampules, prepares the concentrates, and seals the ampules. A different person then analyzes the sample blindly. For the particulate fractions (particulate carbon/particulate nitrogen and particulate phosphorus), samples are filtered and then placed in pouches in the freezer until they are ready to be sent to the other CBP participating laboratories. As of 2-May-2019 the following labs were participating in the Blind Audit program: College of William and Mary - Virginia Institute of Marine Science, Analytical Services Center; Delaware DNREC-DWR; Hampton Roads Sanitation District - CEL; Maryland Department of Health, Division of Environmental Sciences, Inorganics Analytical Laboratory; Massachusetts Water Resource Authority; Microbac Laboratories Inc.; New Jersey Public Health, E&A Lab, New Jersey State Police HQ Campus; Old Dominion University, Water Quality Laboratory; Patrick Center for Environmental Research - Academy of Natural Sciences of Philadelphia; Pennsylvania Department of Environmental Protection - Bureau of Laboratories; Sprague River Water Quality Laboratory; University of Connecticut Center for Environmental Science and Engineering; University of Maryland, CES, Appalachian Laboratory; University of Maryland, CES, Chesapeake Biological Laboratory; University of Maryland, CES, Horn Point Laboratory; Virginia Division of Consolidated Laboratory Services and Virginia Polytechnic Institute - Occoquan Laboratory.

Once annually, the EPA Chesapeake Bay Program quality assurance officer conducts an on-site audit of the Shallow Water Quality Monitoring laboratory and field programs. The DNR Quality Assurance Officer communicates on a weekly basis with the field program staff and confers with the laboratory quality assurance officers to ensure that all aspects of the program are being conducted properly.

## 6.5 Data Quality Indicators

To ensure that data are of the quality required to support Chesapeake Bay Program management decisions, Maryland's Shallow Water Quality Monitoring Program strives to provide monitoring data of known and consistent quality to the CBPO by generally following the guidelines outlined in Section E of the [Methods and Quality Assurance for Chesapeake Bay Water Quality Monitoring Programs, May 2017](#) (EPA 2017). These guidelines recommend precision goals of field and lab measurements of <20 percent of the coefficient of variation, accuracy goals within 80 to 120 percent, and completeness goals of 100 percent. Detection limit ranges are provided in Tables 7, 8, and 9 above.

## 7. DATA ANALYSIS AND REPORTING

As noted previously, the objectives of the Shallow Water Monitoring Program are to 1) assess the newly developed Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow and open water habitats, 2) determine attainment or non-attainment of shallow water and open water habitats for their designated uses, 3) provide spatially and temporally intensive data in shallow water habitats to improve water quality mapping using interpolation, 4) assess SAV habitats and identify potential SAV restoration sites and 5) provide information to better understand ecosystem processes in shallow water and open water environments.

Regression models for use in calculating  $K_d$  from *in situ* turbidity, chlorophyll and salinity data have been developed and continue to be refined as new data become available. The  $K_d$  models have been used in five reporting cycles for water clarity acreage assessments.

Real-time data (uploaded from transmitters hourly) and near-time data (uploaded every two weeks) will be available on the DNR Eyes on the Bay web site (<http://www.eyesonthebay.net>). These data are not quality assured and will be identified as such. Archived data from prior years (2001 – 2018) are “Quality Assured” and also available for download on the Eyes on the Bay web site. Semi-annual progress reports will be provided to the Chesapeake Bay Program July 15, 2019 and January 15, 2020.

## 8. PROJECT ORGANIZATION AND RESPONSIBILITY

This section lists the individuals responsible for the major aspects of Maryland's Shallow Water Quality Monitoring Program.

Director and Principal Investigator: Thomas Parham, Director, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, tom.parham@maryland.gov, 410-260-8633.

**RESPONSIBILITIES:** The director and principal investigator is responsible for overseeing the administrative aspects of the program including fiscal management, coordination among other DNR managers and coordination with cooperating agencies and institutions. This individual is also responsible for technical design, conduct and data analysis of the program.

Quality Assurance Officer: Christine Conn, Ph.D., Director, Office of Science and Stewardship, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, christine.conn@maryland.gov, 410-260-8785.

**RESPONSIBILITIES:** The quality assurance officer is responsible for documenting and assuring the conduct of field, laboratory, and data management procedures that comprise this study.

Field Sampling Operations: Kristen Heyer, Program Manager, Water Quality Monitoring, Monitoring and Non-Tidal Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, kristen.heyer@maryland.gov, 410-990-4600.

**RESPONSIBILITIES:** This individual is responsible for administration of field sampling activities including sample collection, sample storage and sample delivery to laboratories at all continuous monitoring sites and most water quality mapping sites.

Instrument Management: John Zimmerelli, Natural Resources Biologist, Monitoring Field Office, Monitoring and Non-Tidal Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, john.zimmerelli@maryland.gov, 410-990-4505.

**RESPONSIBILITIES:** This individual is responsible for the management of all continuous monitoring equipment.

Instrument Management: Jamie Strong, Natural Resources Biologist, Monitoring Field Office, Monitoring and Non-Tidal Assessment, Resource Assessment Service, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, jamie.strong@maryland.gov, 410-990-4508.

**RESPONSIBILITIES:** This individual is responsible for the management of all water quality mapping and vertical profiler equipment.

Laboratory Analyses/Water Column Chemistry: Jerry Frank, Manager of Analytical Services/Senior Faculty Research Assistant, Chesapeake Biological Lab, University of Maryland, Center for Environmental Science, Solomons, Maryland 20688-0038, frank@cbl.umces.edu, 410-326-7252.

**RESPONSIBILITIES:** This individual is responsible for analysis of water samples for suspended solids, nutrients and chlorophyll.

Data Management: Mark Trice/Brian Smith/Ben Cole/Renee Karrh/Diana Domotor/Rebecca Burrell, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, 410-260-8630.

RESPONSIBILITIES: These individuals are responsible for overseeing the management of field and laboratory data collected under this program; managing historical field and laboratory data collected under this program; and maintaining existing data management software.

Data Analysis and Report Preparation: Mark Trice/Brian Smith/Renee Karrh/Ben Cole/Diana Domotor/Rebecca Burrell, Tidewater Ecosystem Assessment, Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, Maryland 21401, 410-260-8630.

RESPONSIBILITIES: These individuals are responsible for statistical analyses, GIS mapping, and report preparation under this program.

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## Appendix 1. YSI 6600EDS Specification Sheets

YSI 6600EDS Sensor Specifications				
		Range	Resolution	Accuracy
Dissolved Oxygen* % Saturation 6562 Rapid Pulse™ Sensor*	ET✓	0 to 500%	0.1%	0 to 200%; ±2% of reading or 2% air saturation, whichever is greater; 200 to 500%; ±6% of reading
Dissolved Oxygen* mg/L 6562 Rapid Pulse™ Sensor*	ET✓	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L; ± 0.2 mg/L or 2% of reading, whichever is greater; 20 to 50 mg/L; ±6% of reading
Conductivity** 6560 Sensor*	ET✓	0 to 100 mS/cm	0.001 to 0.1 mS/cm (range dependent)	±0.5% of reading + 0.001 mS/cm
Salinity		0 to 70 ppt	0.01 ppt	±1% of reading or 0.1 ppt, whichever is greater
Temperature 6560 Sensor*	ET✓	-5 to +50°C	0.01°C	±0.15°C
pH 6561 Sensor*	ET✓	0 to 14 units	0.01 unit	±0.2 unit
ORP		-999 to +999 mV	0.1 mV	±20 mV
Depth	Deep Medium Shallow Vented Level	0 to 656 ft, 200 m 0 to 200 ft, 61 m 0 to 30 ft, 9.1 m 0 to 30 ft, 9.1 m	0.001 ft, 0.001 m 0.001 ft, 0.001 m 0.001 ft, 0.001 m 0.001 ft, 0.001 m	±1 ft, ±0.3 m ±0.4 ft, ±0.12 m ±0.06 ft, ±0.02 m ±0.01 ft, 0.003 m
Turbidity* 6136 Sensor*	ET✓	0 to 1,000 NTU	0.1 NTU	±2% of reading or 0.3 NTU, whichever is greater**
Rhodamine*		0-200 µg/L	0.1 µg/L	±5% reading or 1 µg/L, whichever is greater

\* Maximum depth rating for all standard optical sensors is 200 feet, 61 m. Also available in Deep Depth option: 656 feet, 200 m.  
 \*\* Report outputs of specific conductance (conductivity corrected to 25°C), resistivity, and total dissolved solids are also provided. These values are automatically calculated from conductivity according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (ed 1989).  
 \*\*In YSI AMCO-AEPA Polymer Standards.

		Range	Detection Limit	Resolution	Linearity
BGA - Phycocyanin*		~0 to 280,000 cells/mL† 0 to 100 RFU	~220 cells/mL‡	1 cell/mL 0.1 RFU	R <sup>2</sup> > 0.9999**
BGA - Phycoerythrin*		~0 to 200,000 cells/mL† 0 to 100 RFU	~450 cells/mL‡	1 cell/mL 0.1 RFU	R <sup>2</sup> > 0.9999***
Chlorophyll* 6025 Sensor*	ET✓	~0 to 400 µg/L 0 to 100 RFU	~0.1 µg/L‡‡‡	0.1 µg/L Chl 0.1% RFU	R <sup>2</sup> > 0.9999****

† Explanation of Ranges can be found in the 'Principles of Operation' section of the 6-Series Manual.  
 ‡ Estimated from cultures of *Microcystis aeruginosa*.  
 ‡‡ Estimated from cultures *Synechococcus sp.*  
 ‡‡‡ Determined from cultures of *Isochrysis sp.* and chlorophyll *a* concentration determined via extractions.  
 \*\*Relative to serial dilution of Rhodamine WT (0-400 µg/L).  
 \*\*\*Relative to serial dilution of Rhodamine WT (0-8 µg/L).  
 \*\*\*\*Relative to serial dilution of Rhodamine WT (0-500 µg/L).  
 BGA = Blue-Green Algae  
 RFU = Relative Fluorescence Units  
 ~ = Approximately

YSI 6600EDS Sonde Specifications				
Medium		Fresh, sea or polluted water	Software	EcoWatch*
Temperature	Operating Storage	-5 to +50°C -10 to +60°C	Dimensions	Diameter Length, no depth Length, depth Weight, depth and batteries
Communications		RS-232, SDI-12	Power	External Internal

3.5 in, 8.9 cm  
 19.6 in, 34.3 cm  
 21.6 in, 54.9 cm  
 7 lbs, 3.18 kg  
 12 V DC  
 8 C-size alkaline batteries

## Appendix 1 (continued). YSI 6600V2 Specification Sheets

YSI 6600 V2 Sensor Specifications			
	Range	Resolution	Accuracy
ROX™ Optical Dissolved Oxygen* % Saturation	0 to 500%	0.1%	0 to 200%; ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%; ±15% of reading
ROX™ Optical Dissolved Oxygen* mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ±0.1 mg/L or 1% of reading, whichever is greater; 20 to 50 mg/L: ±15% of reading
Dissolved Oxygen** % Saturation 6562 Rapid Pulse™ Sensor*	ET✓ 0 to 500%	0.1%	0 to 200%; ±2% of reading or 2% air saturation, whichever is greater; 200 to 500%; ±6% of reading
Dissolved Oxygen** mg/L 6562 Rapid Pulse™ Sensor*	ET✓ 0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ±0.2 mg/L or 2% of reading, whichever is greater; 20 to 50 mg/L: ±6% of reading
Conductivity*** 6560 Sensor*	ET✓ 0 to 100 mS/cm	0.001 to 0.1 mS/cm (range dependent)	±0.5% of reading + 0.001 mS/cm
Salinity	0 to 70 ppt	0.01 ppt	±1% of reading or 0.1 ppt, whichever is greater
Temperature 6560 Sensor*	ET✓ -5 to +50°C	0.01°C	±0.15°C
pH 6561 Sensor*	ET✓ 0 to 14 units	0.01 unit	±0.2 unit
ORP	-999 to +999 mV	0.1 mV	±20 mV
Depth	Deep Medium Shallow Vented Level	0 to 656 ft, 200 m 0 to 200 ft, 61 m 0 to 30 ft, 9.1 m 0 to 30 ft, 9.1 m	0.001 ft, 0.001 m 0.001 ft, 0.001 m 0.001 ft, 0.001 m 0.001 ft, 0.001 m
Turbidity* 6136 Sensor*	ET✓ 0 to 1,000 NTU	0.1 NTU	±2% of reading or 0.3 NTU, whichever is greater**
Nitrate/nitrogen****	0 to 200 mg/L-N	0.001 to 1 mg/L-N (range dependent)	±10% of reading or 2 mg/L, whichever is greater
Ammonium/ammonia/ nitrogen****	0 to 200 mg/L-N	0.001 to 1 mg/L-N (range dependent)	±10% of reading or 2 mg/L, whichever is greater
Chloride****	0 to 1000 mg/L	0.001 to 1 mg/L (range dependent)	±15% of reading or 5 mg/L, whichever is greater
Rhodamine*	0-200 µg/L	0.1 µg/L	±5% reading or 1 µg/L, whichever is greater

\* Maximum depth rating for all optical probes is 200 feet, 61 m. Turbidity and Rhodamine are also available in a Deep Depth option (0 to 200 m).  
 \*\* Rapid Pulse is only available on 6600 V2-2 (two optical ports version).  
 \*\*\* Report outputs of specific conductance (conductivity corrected to 25°C), resistivity, and total dissolved solids are also provided. These values are automatically calculated from conductivity according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (ed 1989).  
 \*\*\*\* Freshwater only. Maximum depth rating of 50 feet, 15.2 m. 6600 V2-2 has 3 ISE ports; not available on the 6600V2-4.

\*\*In YSI AMCO-AEFA Polymer Standards.

	Range	Detection Limit	Resolution	Linearity
Blue-Green Algae Phycocyanin*	~0 to 280,000 cells/mL† 0 to 100 RFU	~220 cells/mL‡	1 cell/mL 0.1 RFU	R <sup>2</sup> > 0.9999**
Blue-Green Algae Phycocerythrin*	~0 to 200,000 cells/mL† 0 to 100 RFU	~450 cells/mL‡§	1 cell/mL 0.1 RFU	R <sup>2</sup> > 0.9999***
Chlorophyll* 6025 Sensor*	ET✓ ~0 to 400 µg/L 0 to 100 RFU	~0.1 µg/L‡§§	0.1 µg/L Chl 0.1 RFU	R <sup>2</sup> > 0.9999****

\* Maximum depth rating for all optical probes is 200 feet, 61 m. Also available in a Deep Depth option (0 to 200 m). RFU = Relative Fluorescence Units  
 † Explanation of Ranges can be found in the 'Principles of Operation' section of the 6-Series Manual, Rev. D.  
 ‡ Estimated from cultures of *Microcystis aeruginosa*.  
 § Estimated from cultures *Synechococcus* sp.  
 §§ Determined from cultures of *Coelastrum* sp. and chlorophyll *a* concentration determined via extractions.  
 \*\* For serial dilution of Rhodamine WT (0-400 µg/L).  
 \*\*\* For serial dilution of Rhodamine WT (0-8 µg/L).  
 \*\*\*\* For serial dilution of Rhodamine WT (0-500 µg/L).

YSI 6600 V2 Sonde Specifications			
Medium	Fresh, sea or polluted water	Software	EcoWatch*
Temperature	Operating Storage	Dimensions	Diameter Length, no depth Length, with depth Weight
	-5 to +50°C -10 to +60°C		3.5 in, 8.9 cm 19.6 in, 49.8 cm 21.6 in, 54.9 cm 7 lbs, 3.18 kg (batteries installed, with depth)
Communications	RS-232, SDI-12	Power	External Internal
			12 V DC 8 C-size alkaline batteries

## Appendix 1 (continued). YSI EXO2 Specification Sheets

### Sensor Specifications\*

Sensor	Range	Accuracy*	Response	Resolution
Ammonium <sup>11</sup> (ammonia with pH sensor)	0 to 200 mg/L <sup>1</sup>	±10% of reading or 2 mg/L-N, w.i.g.	-	0.01 mg/L
Barometer	375 to 825 mmHg	±1.5 mmHg from 0 to 50°C	-	0.1 mmHg
Blue-green Algae Phycocyanin (PC) (part of Total Algae sensor)	0 to 100 RFU; 0 to 100 µg/L PC	Linearity: R <sup>2</sup> > 0.999 for serial dilution of Rhodamine WT solution from 0 to 100 µg/mL PC equivalents	T63<2 sec	0.01 RFU; 0.01 µg/L PC
Blue-green Algae Phycocerythrin (PE) (part of Total Algae sensor)	0 to 100 RFU; 0 to 280 µg/L PE	Linearity: R <sup>2</sup> > 0.999 for serial dilution of Rhodamine WT solution from 0 to 280 µg/mL PE equivalents	T63<2 sec	0.01 RFU; 0.01 µg/L PE
Chloride <sup>11</sup>	0 to 18000 mg/L-Cl <sup>2</sup>	±15% of reading or 5 mg/L-Cl, w.i.g.	-	0.01 mg/L
Chlorophyll (part of Total Algae sensor)	0 to 400 µg/L Chl; 0 to 100 RFU	Linearity: R <sup>2</sup> > 0.999 for serial dilution of Rhodamine WT solution from 0 to 400 µg/L Chl equivalents	T63<2 sec	0.01 µg/L Chl; 0.01 RFU
Conductivity <sup>3</sup>	0 to 200 mS/cm	0 to 100: ±0.5% of reading or 0.001 mS/cm, w.i.g.; 100 to 200: ±1% of reading	T63<2 sec	0.0001 to 0.01 mS/cm (range dependent)
Depth <sup>4</sup> (non-vented)	0 to 10 m (0 to 33 ft)	±0.04% FS (±0.004 m or ±0.013 ft)	T63<2 sec	0.001 m (0.001 ft) (auto-ranging)
	0 to 100 m (0 to 328 ft)	±0.04% FS (±0.04 m or ±0.13 ft)		
	0 to 250 m (0 to 820 ft)	±0.04% FS (±0.10 m or ±0.33 ft)		
Vented Level	0 to 10 m (0 to 33 ft)	±0.03% FS (±0.003 m or ±0.010 ft)		
Dissolved Oxygen Optical	0 to 500% air saturation	0 to 200%: ±1% of reading or 1% saturation, w.i.g.; 200 to 500%: ±5% of reading <sup>5</sup>	T63<5 sec <sup>6</sup>	0.1% air saturation
	0 to 50 mg/L	0 to 20 mg/L: ±0.1 mg/L or 1% of reading, w.i.g.; 20 to 50 mg/L: ±5% of reading <sup>5</sup>		0.01 mg/L
fDOM	0 to 300 ppb Quinine Sulfate equivalents (QSE)	Linearity: R <sup>2</sup> > 0.999 for serial dilution of 300 ppb QS solution Detection Limit: 0.07 ppb QSE	T63<2 sec	0.01 ppb QSE
Nitrate <sup>11</sup>	0 to 200 mg/L-N <sup>1</sup>	±10% of reading or 2 mg/L-N, w.i.g.	-	0.01 mg/L
ORP	-999 to 999 mV	±20 mV in Redox standard solutions	T63<5 sec <sup>7</sup>	0.1 mV
pH	0 to 14 units	±0.1 pH units within ±10°C of calibration temp; ±0.2 pH units for entire temp range <sup>8</sup>	T63<3 sec <sup>9</sup>	0.01 units
Salinity (Calculated from Conductivity and Temperature)	0 to 70 ppt	±1.0% of reading or 0.1 ppt, w.i.g.	T63<2 sec	0.01 ppt
Specific Conductance (Calculated from Cond. and Temp.)	0 to 200 mS/cm	±0.5% of reading or .001 mS/cm, w.i.g.	-	0.001, 0.01, 0.1 mS/cm (auto-scaling)
Temperature	-5 to 50°C	-5 to 35°C: ±0.01°C <sup>10</sup> 35 to 50°C: ±0.05°C <sup>10</sup>	T63<1 sec	0.001 °C
Total Dissolved Solids (TDS) (Calculated from Conductivity and Temperature)	0 to 100,000 mg/L Cal constant range 0.30 to 1.00 (0.64 default)	Not Specified	-	variable
Total Suspended Solids (TSS) (Calculated from Turbidity and user reference samples)	0 to 1500 mg/L	Not Specified	T63<2 sec	variable
Turbidity <sup>11</sup>	0 to 4000 FNU	0 to 999 FNU: 0.3 FNU or ±2% of reading, w.i.g.; 1000 to 4000 FNU: ±5% of reading <sup>12</sup>	T63<2 sec	0 to 999 FNU: 0.01 FNU; 1000 to 4000 FNU: 0.1 FNU

All sensors have a depth rating to 250 m (820 ft), except shallow and medium depth sensors and ISEs. EXO sensors are not backward compatible with 6-Series sondes.

\* Specifications indicate typical performance and are subject to change. Please check EXOwater.com for up-to-date information.

Accuracy specification is attained immediately following calibration under controlled and stable environmental conditions. Performance in the natural environment may vary from quoted specification.

<sup>1</sup> 0-30°C    <sup>2</sup> 0-40°C    w.i.g. = whichever is greater

<sup>3</sup> Outputs of specific conductance (conductivity corrected to 25°C) and total dissolved solids are also provided. The values are automatically calculated from conductivity according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (Ed. 1989).

<sup>4</sup> Accuracy specifications apply to conductivity levels of 0 to 100,000 µS/cm.

<sup>5</sup> Relative to calibration gases

<sup>6</sup> When transferred from air-saturated water to stirred deaerated water

<sup>7</sup> When transferred from water-saturated air to Zobell solution

<sup>8</sup> Within the environmental pH range of pH 4 to pH 10

<sup>9</sup> On transfer from water-saturated air to rapidly stirred air-saturated water at a specific conductance of 800 µS/cm at 20°C; T63<5 seconds on transfer from water-saturated air to slowly-stirred air-saturated water.

<sup>10</sup> Temperature accuracy traceable to NIST standards

<sup>11</sup> Calibration: 1-, 2-, or 3-point, user-selectable

<sup>12</sup> Specification is defined in AMCO-AEPA Standards

**Appendix 1 (continued). YSI EXO2 Specification Sheets (continued)**

<b>EXO2 Sonde</b>	
Ports	7 sensor ports (6 ports available when central wiper used) Peripheral ports: 1 power communication port; 1 auxiliary expansion port
Size	Diameter: 7.62 cm (3.00 in) Length: 71.10 cm (28.00 in)
Weight	3.60 kg (7.90 lbs) with 5 probes, guard and batteries installed
<b>Sondes</b>	
Operating Temperature	-5 to 50°C
Storage Temperature	-20 to 80°C (except 0 to 60°C for pH and pH/ORP sensors)
Depth Rating	0 to 250 m (0 to 820 ft)
Communications	Computer Interface: Bluetooth wireless technology, RS-485, USB Output Options: USB with signal output adapter (SOA); RS-232 & SDI-12 with DCP-SOA
Sample Rate	Up to 4 Hz
Battery Life	90 days**
Data Memory	512 MB total memory; >1,000,000 logged readings

## **Appendix 2. Continuous Monitoring Procedures**

*C. Trumbauer, J. Zimmerelli*

Revised: April 2014

### **Installation:**

- To collect seamless continuous data, two instruments are needed for each site. Deploy the first instrument at the site for two to four weeks. At the end of the deployment, replace this instrument with the second instrument. During the next week, post-calibrate and clean the first instrument and prepare it to be deployed the next week.
- Use a 4" diameter PVC gasketed drain pipe to install a site. The length depends on the depth of the selected site.
- Coat the PVC pipe with an effective anti-fouling paint to prevent biological contamination.
- Drill 2" diameter holes down the length of the PVC pipe that will typically lie below the water line to allow water to pass through the tube.
- Attach the tube to a wooden 2x4 using two copper or stainless steel clevis hangers. Then attach the 2x4 to a piling or pier using lag bolts.
- Install a stop bolt at the bottom of the tube to prevent the loss of a sonde.
- Place a chain through the tube, and lock it with a combination or key lock to prevent theft or vandalism.

### **Calibration:**

- Calibrate each instrument using laboratory quality standards directly prior to each deployment (see Appendix 5).
- Synchronize the internal clock in the instrument and all watches with the official time. A radio-controlled clock that automatically synchronizes to the Atomic Clock in Boulder, CO can also be used. Time is always set in Eastern Standard Time.

### **Deployment:**

- Deploy the instrument at a fixed site at a regular interval, e.g., weekly, bi-weekly, or monthly.
- Record the date, location, weather conditions, tide, time of deployment, and initials on the calibration log, and note any extra samples taken.
- Leave the instrument that was deployed the prior week in place inside the PVC tube while suspending the freshly calibrated instrument at the same depth, adjacent to the old one. Allow both instruments to take at least one simultaneous reading in order to compare the data from the two instruments. This comparison is used during QA/QC process to ensure both instruments were taking accurate measurements
- Use a YSI, Hydrolab, or similar instrument with a display unit to take an additional simultaneous reading. The real-time display makes it possible to note any sudden fluctuations or trends in the water quality parameters.
- At exact time of sample reading, take a grab sample using an Alpha bottle suspended at the same depth as the sondes.

### **Sample Processing:**

- Grab sample is filtered immediately after it is taken. Sample is filtered according to Chesapeake Bay Program protocol (see Appendix 7).
- Processed sample is iced down in the field, and frozen in a freezer upon return to the field office, with the exception of samples for alkalinity which are kept chilled but not frozen. It is then sent to lab for analysis at the end of the week via courier.

**Water Column Profile:**

Water column profiles should be taken at each continuous monitoring station when the YSI 6600 or EXO sondes are being replaced. This profile will be done with the check instrument (e.g., Hydrolab) and will measure the following parameters:

- Depth
- Water Temperature (°C)
- pH
- Specific Conductance (µmhos/cm)
- Dissolved Oxygen (mg/l)
- Salinity (ppt)

There should be NO layer code associated with these additional measurements. Layer codes are assigned only to those measurements taken at the same depth as the grab sample.

The following procedure should be followed for the profile:

**If total depth < 3.0 m:****Floating Stations:**

Take Hydrolab readings at the same depth at which the YSI is suspended (1.0 m). This should be done at the exact instant that the YSI is logging its data. Next take Hydrolab readings at 0.3 m from the bottom. You must also take readings at 0.5 m depth, and 0.5 m intervals, e.g. 1.5, 2.0, 2.5, etc. You do not need to take readings within 0.2 m of a depth you already measured.

*Examples:*

*Total depth = 1.7 m:*

*Hydrolab readings at 1.0; then 1.4 and 0.5 m. You do not need to sample 1.5 m since it is within 0.2 m of the bottom reading*

*Total depth = 2.9 m:*

*Hydrolab readings at 1.0; then 2.6, 2.0, 1.5 and 0.5 m.*

*Total depth = 2.4 m:*

*Hydrolab readings at 1.0; then 2.1, 1.5 and 0.5 m. You do not need to sample 2.0 m since it is within 0.2 m of the bottom reading*

**Fixed Stations (0.3 m above bottom):**

Take Hydrolab readings at the same depth at which YSI is fixed (0.3 m from the bottom.) This should be done at the exact instant that the YSI is logging its data. You must also take readings at 0.5 m, and any 0.5 m intervals, e.g. 1.5, 2.0, 2.5, etc. You do not need to take readings within 0.2 m of a depth you already measured.

*Examples:*

*Total depth = 0.7 m:*

*Hydrolab readings at 0.4 m only*

*Total depth = 1.9 m:*

*Hydrolab readings at 1.6, 1.0 and 0.5 m. You do not need to sample 1.5 m since it is within 0.2 m of the bottom reading*

*Total depth = 1.5 m:*

*Hydrolab readings at 1.2 and 0.5 m. You do not need to sample 1.0 m since it is within 0.2 m of the bottom reading.*

### **Fixed Stations (0.5 m above bottom)**

Take Hydrolab readings at the same depth at which YSI is fixed (0.5 m from the bottom.) This should be done at the exact instant that the YSI is logging its data. You must also take readings at 0.5 m, and any 1.0 m intervals, e.g. 1.5, 2.0, 2.5, etc. You do not need to take readings within 0.2 m of a depth you already measured.

*Example:*

*Total depth = 1.9 m:*

*Hydrolab readings at 1.4, 1.0 and 0.5 m.*

### **If Total Depth $\geq$ 3.0 m:**

#### **Floating Stations:**

Take Hydrolab readings at the same depth at which the YSI is suspended (1.0 m). This should be done at the exact instant that the YSI is logging its data. Next take Hydrolab readings at 0.3 m from the bottom. You must also take readings at 0.5 m depth, and 1.0 m intervals, e.g. 2.0, 3.0, etc. You do not need to take readings within 0.2 m of a depth you already measured.

*Examples:*

*Total depth = 3.4 m:*

*Hydrolab readings at 1.0; then 3.1, 2.0 and 0.5 m. You do not need to sample 3.0 m since it is within 0.2 m of the bottom reading*

#### **Fixed Stations (0.3 m above bottom):**

Take Hydrolab readings at the same depth at which YSI is fixed (0.3 m from the bottom.) This should be done at the exact instant that the YSI is logging its data. You must also take readings at 0.5 m, and any 1.0 m intervals, e.g. 2.0, 3.0, etc. You do not need to take readings within 0.2 m of a depth you already measured.

*Examples:*

*Total depth = 3.2 m:*

*Hydrolab readings at 2.9, 2.0, 1.0 and 0.5 m.*

#### **Stations sampled 0.5 m above bottom:**

Take Hydrolab readings at the same depth at which YSI is fixed (0.5 m from the bottom.)

This should be done at the exact instant that the YSI is logging its data. You must also take readings at 0.5 m, and any 1.0 m intervals, e.g. 1.0, 2.0, 3.0, etc. You do not need to take readings within 0.2 m of a depth you already measured.

*Examples:*

*Total depth = 3.5 m:*

*Hydrolab readings at 3.0, 2.0, 1.0 and 0.5 m.*

**Retrieval:**

- After both instruments have been allowed to take at least one simultaneous reading, remove the old instrument. It is best to take a second simultaneous reading whenever possible.
- Record the date, location, weather conditions, tide, time of retrieval, and initials on the calibration log, and note any extra samples taken.
- Brush out the instrument tube with a Webster-type brush, on the inside and outside.
- Deploy the fresh instrument in its place.
- Wrap the old instrument in a damp towel and take it back to the lab for post-calibration and cleaning.

**Post-calibration/cleaning:**

- Post-calibrate sensors on each retrieved instrument against laboratory standards to ensure that it was taking accurate measurements. It is best to complete sensor post-calibration procedures the day after the instrument is retrieved, after allowing the instrument to equilibrate to standard temperature and pressure overnight in 100% saturated air environment before conducting the post-calibration. If using an Optical Dissolved Oxygen sensor, the dissolved oxygen can be post-calibrated within 20 minutes of returning from the field by placing the instrument in a bucket of 100% air saturated water and allowing temperature and pressure to equilibrate. If field staff are unable to calibrate the instrument the day after retrieval, ensure that the instrument is post-calibrated by the second day after retrieval.
- After completion of post-calibration, thoroughly clean each instrument and prepare it for re-deployment the following week.

Figure 4 on the following page is an annotated example of a Continuous Monitoring Field data sheet.

NOTE: Beginning May 18, 2009, in order resolve a data management issue, Continuous Monitoring grab sample bottles and grab sample replicate bottles are labeled as follows.

Samples are collected every other week, up to three samples a month. The bottle of the first samples collected in a month should be labeled with a number from 1 to 99. Sample bottles collected the second or third time in any month should be labeled with 100 or 200 series numbers respectively. Sample bottles collected during the second sampling of any month should be labeled with a number from 100 to 199. Sample bottles collected during the third sampling of any month should be labeled with a number from 200 to 299.

For example, a sample bottle collected during the first sampling of a month might have the sample number 5, if the sample is collected in the second sampling of the month the sample number might be 105, if the sample is collected during the third sampling of the month, the sample number might be 205.

Replicate sample bottles should be labeled with 700 or 800 or 900 series numbers depending on the collection week. For example, a replicate sample bottle collected during the first sampling of a month might have the sample number 705, if the replicate sample is collected during the second sampling of the month, the sample number might be 805, if the replicate sample is collected during the third sampling of the month the sample number might be 905.

Grab samples collections in one month			
Bottle Numbers example	1st time	2nd time	3rd time
bottle number 6	6	106	206
bottle number 6 replicate	706	806	906
bottle number 14	14	114	214
bottle number 14 replicate	714	814	914



### **Appendix 3. Water Quality Mapping Procedures**

*A.J. Strong, B. Cole, W. Nelson*

Revised: April 2018

*The Water Quality Mapping project currently uses three different types of equipment units. They are referred to as “new unit”, “laptop unit.”, and “R/V Kerhin method” Procedures for the three units are detailed below.*

#### **Water Quality Mapping Procedures (New Unit)**

##### **Equipment Setup:**

1. Attach stainless steel ram to boat, before or after launching boat, using pre-drilled holes thru the port or starboard side transom of the boat with two bolts, two lock washers, and two nuts provided. Securely tighten with a 15/16” wrench or other suitable tool.
2. Attach depth finder transducer bracket to ram by inserting metal rod up thru hole in splash plate making sure that pointed side of transducer is facing the bow (front) of boat. Also make sure the transducer is below boat hull and water line. Securely tighten setscrew with 9/16” wrench or other suitable tool.
3. Launch research vessel.
4. After launching, insert gray PVC pipe with attached Rule 1100 live well pump down thru stainless steel ram and securely tighten with lever on ram.
5. Attach YSI Sensor Unit stand (big white thing about three feet tall with flow meter alarm and GPS antenna) to starboard or port side of research vessel using bolts, lock-washers, and nuts provided or other suitable means
6. Connect 1” diameter black hose to ram pump with a hose clamp or quick connect assembly and attach other end of hose to the **intake** port of the YSI Sensor Unit stand with a hose clamp or quick connect assembly. This port connects directly to grey YSI Flow-cell.
7. Connect the other 1” diameter clear hose to the YSI Sensor Unit stand **outflow** port and leave the other end of hose hanging over the starboard side or back of the boat.
8. Unscrew calibration cup from YSI and insert the probe end of the meter into the YSI grey flow-cell that is already mounted on the YSI meter stand, turn until meter will turn no more and then tighten it.
9. Prime the DATAFLOW ram by removing Rule 1100 pump head and pouring water into pipe until full. Replace Rule 1100 pump head.

##### **External Power Hook-up:**

1. Take YSI 9 pin cable and attach it to the YSI meter. Attach other end of cable to the designated “J3” connector on the case housing of the Processor Unit (small yellow suitcase).
2. Attach one end of GPS cable to the connector on side of the Sensor Unit and connect the other end of cable to the designated “J4” connector on the Processor Unit.
3. Attach one end of the 12 pin Flow meter cable to the connector on the side of the Sensor unit and connect the other end of the cable to the designated “J2” connector on the Processor Unit.
4. Connect the end of the transducer cable to the designated “J5” connector on the side of the Processor Unit.
5. Attach 3 pin Power cable (cable with power winch plug on one end) to the designated “J1” connector on the Processor Unit.
6. Take the 26 pin Computer monitor cable and attach one end to the “pig tail” on back of the monitor and the other end to the designated “J6” connector on the side of the Processor Unit.
7. Take the end of the keyboard cable and attach it to the designated “J7” connector on the Processor Unit.

8. Take the power winch plug and connect to the battery box wired with a power winch outlet and 12 volt DC battery.
9. Plug the Rule 1100 pump into the power winch outlet, already installed on the research vessel.
10. Flip DATAFLOW power switch to on.
11. Flip alarm horn switch to on when flow meter reaches 3.0 lpm on flow meter display.

#### **Data Logging:**

1. Turn on GPS by pushing power button on the Garmin GPSmap168 Sounder.
2. When computer has booted up, double click the "DATAFLOW" icon, then click ok when the next box appears, it should say "Labview for Windows". Click the "OK" button.
3. The setup for logging data has to be adjusted in the Labview software. This is done by scrolling down the page and making the following changes to the software settings: YSI byte count = 152; Bytes to write to YSI = 75; GPS port # = 2; pH offset = 30; Chlorophyll offset = 42; DO offset = 63; Turbidity offset = 38, Turbidity length = 5; Battery offset = 71; Conductivity offset = 23.
4. To start logging data click the small white arrow on upper left of screen. Enter a file name when the file dialog box appears, file name should be the name of the river system you are sampling and the date (i.e. Choptank040607). Click "Save". DATAFLOW is now operational and logging data.
5. To stop logging click the green "run" button on the display screen. This will tell the program to complete its routine and stop. You can also click the red "stop sign" button beside the green "run" button.

#### **Downloading the Data after each run:**

1. Plug a USB flash drive into the USB port located inside the Dataflow Box.
2. Click "File" in the DATAFLOW window then click "Open". Change "Files of type" to "All Files". Find the filename that was saved for that run.
3. Right click the filename, than choose "Copy".
4. Exit out of File window by hitting "Esc", than minimize the Dataflow window by clicking the "\_" button in the top right corner.
5. Double click "My Computer", then double click "Removable Disk". Sometimes the drive will be titled as the name brand. (i.e. USDISK 20X, Lexar Media, etc).
6. Right click inside the "Removable Disk" window and select "Paste".
7. After the file has been transferred to the Flash drive, click the "X" in the upper right corner.
8. Next shut the computer down by clicking the "start" button in the lower left corner, then click "Shut down".
9. Remove flash drive and close up Dataflow box.
10. Flip the horn switch, then the power switch off and unplug Dataflow box from battery.

#### Cruise tracks:

Cruise tracks will vary from one tributary to the next depending on its size and shape, and navigational hazards, but will either follow a 6ft. contour along each shore, or a "square wave" pattern traversing from shallow water to deeper water over the length of the tributary; stopping at 4 to 6 calibration stations.

#### Calibration stations:

At each calibration station collect a physical profile using a Hydrolab™, a Secchi depth measurement, a whole water sample for any CBL nutrients and chlorophyll filtering, and a PAR profile using a LiCor.

#### Hydrolab profile:

Collect the 0.5 m readings first. Record the exact minute that the 0.5 m readings are collected as the start time. You must also simultaneously collect the whole water sample for Chlorophyll and Nutrient analysis

at this time. Then lower the sonde to the bottom and take readings 0.3 m above the bottom and every 0.5 m or 1.0 m intervals to the surface depending on the total depth (see below).

If total depth is < 3 m.:

Hydrolab readings will be collected at 0.5 m from the surface and at 0.5 m intervals, and 0.3 m above the bottom.

If total depth is 3 m. or > than 3 m.:

Hydrolab readings will be collected at 0.5 m from the surface and at 1.0 m intervals, and 0.3 m above the bottom.

Whole water samples will be collected from the outflow of the DATAFLOW unit. Collection must be done simultaneously with the 0.5 m Hydrolab™ readings. A numbered 2 qt. bottle will be rinsed 3 times and filled to be used for CBL nutrient samples and a chlorophyll sample. All processed samples will be immediately placed on ice until delivery to the office

As conditions permit, CBL nutrient and chlorophyll filtering will begin as soon as possible. Filtrate will be collected from the PP units only. In addition to standard filtrate samples, 1 TSS (numbered) pad and 1 chlorophyll (unnumbered Whatman) pad will be submitted for analysis. For the Corsica River only, 1 PP (unnumbered Whatman) pads, 1 VSS/TSS (numbered) pad, 2 PC/PN pads, and 1 chlorophyll (unnumbered Whatman) pad will also be submitted for analysis.

### Water Quality Mapping Procedures (Laptop Unit)

#### Equipment Setup:

*Note: When using the DATAFLOW Laptop unit, the Garmin model GPSMAP168 Sounder chartplotting receiver and depth-finder (or any other brand of GPS Chartplotter/Depth Sounder i.e. Raymarine, Furuno, Lowrance, etc.) must be hardwired directly to the vessel using the “power/data” cable supplied as well as a Sealevel SeaLINK single-port USB to RS-232 serial adapter. The YSI must also have internal batteries.*

1. Before launching research vessel, attach stainless steel ram to research vessel using pre-drilled holes thru port or starboard side transom of research vessel with two bolts, two lock washers, and two nuts provided. Securely tighten with a 15/16” wrench or other suitable tool.
2. Launch research vessel.
3. After launching, insert gray PVC pipe with attached Rule 1100 live well pump down through stainless steel ram and securely tighten with lever on ram.
4. Attach YSI Sensor Unit stand (~3 ft. tall board with sonde clamps and grey flow cell) to starboard or port side of research vessel using bolts, lockwashers and nuts provided or other suitable means.
5. Connect 1” diameter **black hose** to ram pump with a hose clamp or quick connect assembly and attach other end of hose to **intake port** of YSI Sensor Unit stand with a hose clamp or quick connect assembly. This port connects directly to grey YSI Flow-cell.
6. Connect 1” diameter **clear hose** to YSI Sensor Unit stand **outflow port** and leave other end of hose hanging over starboard side or back of research vessel.
7. Unscrew calibration cup from YSI and insert probe end of meter into grey YSI Flow-cell already mounted to YSI meter stand, turn until meter will turn no more and then tighten.
8. Prime DATAFLOW ram by removing Rule 1100 pump head and pouring water into pipe until full. Replace Rule 1100 pump head.

### External Hook-up:

1. Attach a YSI 9-pin cable to YSI meter. Attach other end of cable to 9-pin connector on back of laptop.
2. Plug SeaLevel USB plug (which is installed to Garmin GPS Chartplotter/Depth sounder power/data cable) into USB port on side of laptop.
3. Plug Rule 1100 pump into power winch outlet, already installed on research vessel.
4. Turn on Garmin Chartplotter.
5. Turn on laptop.

### Data Logging:

1. When laptop has booted up, double click “DATAFLOW” icon. Window should open with heading, “Labview for Windows”. Click “OK”.
2. Setup for logging data has to be adjusted in the Labview software. This is done by scrolling down the page and making the following changes to the software settings:

YSI byte count	152
Bytes to write to YSI	75
GPS port #	3
pH offset	30
Chlorophyll offset	42
DO offset	63
Turbidity offset	38
Turbidity length	5
Battery offset	71
Conductivity offset	23

3. To start logging data click small white arrow on upper left corner of screen.
4. Enter a file name when file dialog box appears. File name should be a combination of the name of river system being sampled and the date of sampling (i.e. Choptank040607). Click “Save”. DATAFLOW should now be operational and logging data.
5. To stop logging click green “RUN” button on display screen. This will tell the program to complete its routine and stop. You can also click the red “STOP SIGN” button above the green “RUN” button.

### Downloading the Data after each run:

1. Plug a USB flash drive into USB port located on right side of laptop.
2. Click “File” in the DATAFLOW window, then click “Open”.
3. Change “Files of type” to “All Files”. Find the filename that was saved for that run.
4. Right click the filename, then choose “Copy”.
5. Exit out of File window by hitting “Esc”, then minimize DATAFLOW window by clicking “\_” button in top right corner.
6. Double click “My Computer”, then double click “Removable Disk”. Sometimes drive will be titled as name brand of USB flash drive (e.g. USDISK 20X, Lexar Media, etc.).
7. Right click inside “Removable Disk” window and select “Paste”.
8. After file has been transferred to USB flash drive, click “X” button in upper right corner.
9. Shut down computer by clicking “Start” button in lower left corner, then click “Shut Down” button.

10. Remove USB flash drive.
11. Turn GPS unit off and unplug DATAFLOW pump.

### **Water Quality Mapping Procedures (R/V Kerhin (or other large vessel) method)**

#### **Equipment Setup:**

*Note: When using the DATAFLOW R/V Kerhin method, the YSI **must** be setup to log water quality data internally.*

#### **I. YSI SET-UP FOR R/V KERHIN**

- A. Follow the same procedures as you would calibrating YSI sonde for the other DATAFLOW units (Appendix 6).
- B. To initiate sonde to log data during calibration, while in Ecowatch; select RUN, then UNATTENDED SAMPLE. Enter INTERVAL (4 seconds), START DATE (Ideally two hours before cruise starts), START TIME, DURATION (2 days), FILE NAME and SITE. The file name will be the 3 letter station code followed by the 4 digit mmyy. For example CB40417 indicates that the file is for the month of April and year 2017
- C. If battery life is less than 45 days, change batteries. If free disk space is less than 100 kb, delete all files by returning to the main menu, selecting FILE, then DELETE ALL FILES. **NOTE:** *You should check to make sure that all files have been successfully uploaded to the server before deleting them.*
- D. Exit menu back to # prompt and disconnect sonde cable.
- E. Screw on waterproof connector cap.

#### **II. Equipment Setup on R/V Kerhin**

- A. Attach YSI meter stand to the rail of research vessel with a rope.
- B. Unscrew calibration cup from YSI and attach gray YSI Flow-cell.
- C. Place YSI sonde into YSI stand with the YSI Flow-cell up.
- D. Screw 5/8" garden hose with female end from the R/V Kerhin thru hull fitting sea – cock to YSI Flow-cell **IN**.
- E. Connect the 1" diameter black hose to YSI Flow-cell **OUT** and leave the other end of hose hanging over the side of the boat.

#### **III. Downloading the Data after each run:**

- A. Stop logging by selecting RUN, UNATTENDED SAMPLE, and then STOP LOGGING.
- B. Next upload the data. From the main menu select FILE, then QUICK UPLOAD. Select PC6000 and press enter. This will automatically upload the most recent deployment data on to the computer. It will be stored on the C drive in the ECOWWIN folder. Go to the ECOWWIN folder, find the correct file and cut it from the folder. Go to the M drive and find the DATAFLOW folder. From there go to the RAW File folder, then the Main Bay folder. Paste the file into the folder with the appropriate month.

#### **Sonde File and Navigation File Merge:**

The output of the DATAFLOW/LabVIEW system used on small boat surveys contains merged

time, coordinate and sonde results. When the large vessels are used, the LabVIEW component is not used and additional post-processing work is required to merge navigation log files with the sonde files into a single file.

The process is complicated because the navigation log file and the water quality data sonde files are each started at different times and configured with different time increments. While some navigation and sonde records aligned at precisely the same hour:minute:second timestamp, other navigation and sonde record timestamps are close but differ by one or more seconds.

In order to align the sonde time stamps with the navigation timestamps, time offset expressions are used. For example if the sonde and navigation timestamps is 1 second off, a 1 second timestamp offset is used to align the records. Offset values are documented. Often, timestamps match and no adjustment is required. In other instances, 1, 2 or 3 second adjustments are employed to align the navigation and sonde data. Chesapeake Bay Segment CB4MH extends roughly 85 km from North to South. During a survey lasting approximately 7 hours, a 3 second time offset is considered to be sufficiently, geographically precise for the purposes of the project.

Each month, the raw large vessel navigation log file, the raw water quality sonde data file and timestamp bridge file are referenced in a Microsoft Access(tm) database. The bridge timestamp file contains one second interval time records from 06:00:00 through 23:59:59.

Database queries are used to populate a table that joins navigation records with timestamp bridge records and a table that joins water quality sonde records with timestamp bridge records. Then, a final query is used to join the navigation and sonde tables and the result set is saved as a Microsoft Excel workbook.

A series of steps are executed on Excel workbook worksheets that select a subset of the record set generated using the Access database. The first worksheet serves to document the raw, merged navigation-bridge-sonde records set. The second, based on a copy of the first, uses sorting to select sonde and navigation data time stamps that match exactly. The third worksheet, also based on a copy of the first, prepares records for the fourth worksheet. In the fourth worksheet, sonde values are shifted up one row, in relation to navigation record timestamp values. The number of seconds-shifted (offset) needed to align navigation values and sonde values in worksheet rows, is documented in the fourth worksheet. Finally, the last worksheet, combines water quality sonde and navigation values from the second and fourth worksheet results, including time-shift offset values ranging from 0 seconds to 3 seconds.

At this point, the larger vessel merged time, coordinate and sonde results has been transformed to a stage where they are ready for processes described in **Appendix 12**.

## Appendix 4. Photosynthetic Active Radiation Protocol - May 15, 2003

### Underwater Photosynthetically Active Radiation (PAR, 400-700nm)

Downwelling light penetrating the water column (PAR) is measured underwater at several depths to calculate the light attenuation coefficient,  $K_d$ . Simultaneous deck and submersed PAR intensity measurements are taken to account for variability in incident surface irradiance due to changes in cloud cover. Data collected from this procedure may be used to estimate the depth of the photic zone.

1) Equipment: Manufactured by LI-COR, Inc.

- A. LI-192SA, flat cosine Underwater Quantum Sensor
- B. LI-190SA air (deck) reference sensor.
- C. Data Logger (LI-1000 or LI-1400)

2) Parameters:

- 1. EPARU\_Z      Downwelling PAR, measured underwater with sensor pointed up.  
( $\mu\text{M}$ , micromoles/second-meter<sup>2</sup> =  $\mu\text{E}$ , microEinsteins)
- 2. EPAR\_S      PAR measured in air, on board vessel or pier, recorded concurrently with each underwater depth reading ( $\mu\text{M}$ )
- 3. SDEPTH      Sample depth at which PAR reading is recorded (meters)

3) Procedure:

- 1. PAR is determined from the sunny (or unshaded) side of a vessel or pier during daylight hours. Both deck and submersed probes must be away from the shadow of the vessel.
- 2. Check the sensor operation by connecting the deck sensor and underwater sensor to corresponding ports of the Li-Cor data logger, and turn the power on. Check battery level. Cover the sensor and check to see if the output is very near zero. Place the sensor under a light source to assure that it has a positive reading. A negative reading indicates that the polarity of the sensor is reversed, and is plugged into the cable backwards. A very positive or negative reading in the dark indicates a possible short in the cable or some other electrical short.

In the field, mount the deck sensor in a location which is level and unobstructed by shadows. Ensure that sensors are positioned properly on the deck sensor mounting and the lowering frame. Connect deck sensor and underwater sensor to corresponding ports of the sonde, and turn the power on.

- 3. Set instrument averaging constant to display results from previous 10 or 15 seconds.
- 4. Lower the frame until the sensor is just below the surface of the water. At a depth of 0.1 meter (~4 inches), simultaneously record the deck sensor and the underwater readings for the "surface" measurement. If wave action prevents this, take the initial reading at 0.5 meters. Depth of the underwater sensor diffuser below the surface of the water is determined with a calibrated pole or non-stretching rope.
- 5. Lower the frame and take subsequent measurements at depths appropriate to the monitoring location and purpose of the project (see below). Allow the instrument output to stabilize, at least for the averaging period, then record both deck and underwater readings at each depth.

The simultaneous deck and submersed readings are stored by pressing “Enter”. Each record will be stored with a time stamp which will flash on the data logger readout. Record this time. All readings can be subsequently retrieved at the end of the cruise.

#### Shallow Water Monitoring (Data Flow and Fixed Continuous Monitors)

LiCor readings will be collected from the sunny side of the boat; both deck (out of water) and underwater readings will be recorded simultaneously. Allow readings to stabilize before recording data. This normally takes several seconds.

If the total depth is < 3 m:

Record both deck and underwater readings at 0.10m and at 0.25m intervals until 10 % of first underwater reading is reached. \*\*

If the total depth is equal to or > 3 m:

Record both deck and underwater readings at 0.10m and at 0.5m intervals until 10% of first underwater reading is reached.

\*\* If depth is < 0.5m make sure to record at least 3 different depth readings.

Example: If total depth is 0.25m record data from 0.05m, 0.10m and 0.20m

#### 4) Quality control

1. The deck cell should have the highest PAR value, and the underwater sensor output should decrease as the sensor is lowered.
2. Periodically check that sensors are linear and not out of calibration with respect to each other.
3. PAR sensors should be returned to LICOR, Inc. every year, prior to each field season.
4. Replicate PAR profiles are recommended to make sure readings are correct.

#### 5. Reporting

Report the PAR values from the deck sensor and each underwater measurement under the following CIMS data base method codes:

- a. EPARU\_Z F01: Flat cosine sensor LI-192SA
- b. EPAR\_S F01: Deck (reference) sensor LI-190SA
- c. SDEPTH: Sample depth at which PAR reading is recorded, in meters

## 5) Light Attenuation ( $K_d$ ) Calculations

To calculate the light attenuation coefficient ( $K_d$ ), adjust each underwater PAR value by multiplying by the ratio of:

$$\frac{\text{Maximum EPAR}_S \text{ in profile;}}{\text{EPAR}_S \text{ from that DEPTH}}$$

Using adjusted PAR values, calculate  $K_d$  by one of the methods below.

- 1) **Correlation Coefficient:** Plot the natural log of each adjusted PAR value on the x-axis vs. depth, in meters. The slope of the line times (-1) is  $K_d$ ; the y-intercept is the depth of the photic zone.

Raw data for this calculation can be retrieved from the CIMS Data Hub. Under CBP Water Quality Database, “click to get data” and select the “Light Attenuation Data”.

- 2) **SAV 2-point Method:** Calculate  $K_d$  from the (adjusted) PAR values from two different depths according to the equation:

$$K_d = - \frac{(\ln(\text{adjusted PAR deep}) - \ln(\text{adjusted PAR shallow}))}{(\text{Deep Depth} - \text{Shallow Depth})}, \quad \text{or}$$

$$K_d = \ln \frac{\text{adjusted PAR deep/adjusted PAR shallow}}{\Delta \text{Depth (m)}}$$

Calculated  $K_d$  using this method can be retrieved from the CIMS Data Hub (<http://www.chesapeakebay.net/data>). Under CBP Water Quality Database, “click to get data”, then select “Water Quality Data”. CIMS calculates  $K_d$  based on the SAV 2-point method and automatically adjusts the underwater values if air sensor values are present for each depth. PAR values are taken between the most consistent, shallowest, underwater depths and as close to 1 meter below the surface that is available. In most tributary mid-channels the calculator will select values from Depths = 0.1 and 1.0 meters. In Maryland mainstem, values are usually from Depths = 0.5 and 1.5 meters; in Virginia mainstem,  $K_d$  data are calculated with Depths = 1.0 and 2.0 meters.

The CIMS  $K_d$  calculator will not calculate  $K_d$  for any sampling event with only one PAR reading in the first 2 meters of the water column, or if underwater PAR values are negative.

## Appendix 5. YSI 6600V2 Calibration and Post-Calibration Procedures (Continuous Monitoring)

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MD DNR

Revised 5/13/2013

*Program specific protocols have not yet been developed for calibration and post-calibration of EXO2 instruments. Protocols outlined on pages 81-94 in the EXO User Manual (<https://www.y.si.com/File%20Library/Documents/Manuals/EXO-User-Manual-Web.pdf>) will be followed for calibration and post-calibration of EXO2 instruments. Protocols found on pages 68-70 of the “EXO User Manual” will be used for deployment set-up of the EXO sonde. More information on calibration and use of EXO2 instruments can also be found at [www.exo-university.com](http://www.exo-university.com). As more experience is gained with the EXO2 instruments, program specific protocols may be developed.*

### I. SETUP

- A. Remove calibration cup, and set up the YSI with probes facing up.
- B. Attach non-EDS wipers to the chlorophyll and turbidity probes and to the optical DO (ODO) and blue-green algae probes (if applicable). Always use an orange wiper for the chlorophyll probe, a white wiper for the turbidity probe, and a black wiper for the ODO and blue-green algae probes. Remember to align the screw on the wiper with the flat side of the probe post. Be sure the sponge portion is touching the probe firmly, but is not smashed down flat.
- C. Remove waterproof cap from the 9-pin sonde connector and attach sonde cable from laptop to sonde. Inspect connector for cleanliness, bent pins, etc.
- D. Launch Ecowatch and select SONDE from the COMM menu. Choose COM 1 when prompted to select COM port.
- E. Next, type “menu” at the # prompt.
- F. Select SYSTEM, then DATE AND TIME, then TIME.
- G. Enter the correct time. (Obtain the time by consulting a calibrated ConMon watch, or dialing 410.844.1212) **All times must be entered in Eastern Standard Time (EST).**

### II. DEPTH

- A. If the sonde requires depth for the deployment, it will need to be calibrated. The depth needs to be corrected for barometric pressure. Check the barometric pressure using the barometer in the lab.
- B. Consult the barometric pressure/depth chart in the front of the log book. In Ecowatch, go to CALIBRATE, then PRESSURE-ABS. Type the depth value from the chart and hit <Enter>. When the readings have stabilized, hit <Enter>. Record the calibrated depth on the calibration sheet.

### III. SPECIFIC CONDUCTANCE

- A. Attach open-ended calibration cup securely to sonde and rinse probes 3 times with DI water.
- B. Rinse probes 3 times with conductance standard to be used.
- C. Set sonde upright with probes facing up. Fill calibration cup with standard until the standard level is above conductivity block and temperature probe. If any air bubbles are apparent in the conductivity block, remove them by shaking meter gently or dislodging them with a pipette.
- D. From the CALIBRATE menu select CONDUCTIVITY, then SPECIFIC CONDUCTANCE.
- E. Enter the conductance of the standard **in mS/cm**. Example: 2767  $\mu$ S = 2.767mS.
- F. Allow the readings to stabilize. While the readings stabilize check the temperature probe by placing a lab thermometer into the standard. Place it near the temperature probe on the sonde. Compare the YSI temperature with the thermometer temperature. If the difference is greater than 0.3°C, then there is a problem with the temperature probe and it will need to be replaced.

- G. Once the conductance readings have stabilized record the reading before calibration on the calibration sheet and press <Enter>. Record the after calibration value on the calibration sheet.
- H. Return to the main menu.
- I. Select ADVANCED then CAL CONSTANTS. Record CONDUCTIVITY CELL CONSTANT. If the cell constant is out of the acceptable range it indicates a problem with the probe and it will need to be replaced.

#### IV. pH

- A. With open-ended calibration cup securely attached to sonde, rinse probes 3 times with DI water.
- B. Rinse probes 3 times with pH 7 standard.
- C. Set sonde upright with probes facing up. Fill calibration cup with standard until the level is above pH and temperature probes.
- D. Return to main menu. Select CALIBRATE, then PH, then 2-POINT.
- E. Enter <7>, and allow at least 30 seconds for the sonde to stabilize.
- F. When readings have stabilized, record pH reading and temperature. Press <Enter>, and record pH and pH mV after calibration.
- G. Rinse probes 3 times with DI water.
- H. Rinse probes 3 times with pH 10.
- I. Fill calibration cup with standard until the standard level is above pH and temperature probes.
- J. Enter <10> at prompt, and allow at least 30 seconds for the sonde to stabilize.
- K. When readings have stabilized, record pH reading and temperature. Press <Enter>, and record pH and pH mV after calibration.
- L. Calculate pH slope by subtracting the pH 10 mV from the pH 7 mV. If the slope is outside of the acceptable range it indicates a problem and the probe will need to be replaced.
- M. Remove pH standard and rinse probes 3 times with DI water. Remove open-ended calibration cup.

#### V. BLUE-GREEN ALGAE (WHEN NECESSARY)

- A. Prepare blue-green algae rhodamine solution from stock solution.
  - a. Retrieve stock solution from the refrigerator (Rhodamine 20%).
  - b. Warm to room temperature
  - c. Rinse a clean 1000-mL volumetric flask 3 times with DI water
  - d. Fill flask half way with DI water.
  - e. Pipette exactly 1.0mL(PC) or 80µL(PE) of stock solution into the flask.
  - f. Fill the flask to the line with DI water, cap tightly and invert flask several times to homogenize.
  - g. Return stock solution to the refrigerator.
  - h. Fill a tall calibration cup with about ½ way with the blue-green algae solution. Store in a dark box.
- B. From the main menu go to CALIBRATE, then OPTIC B-BGA PE(OR PC), then BGA CELLS/ML. Select 2-POINT and enter <0> as the cells/mL.
- C. Place the probes in a tall calibration cup filled about ½ way with DI water.
- D. Press <3> to engage wipers. Watch all wipers to make sure that they wipe properly. Wipers should go around twice and then once in the opposite direction. They should park 180° from the sensor. Also make sure there are no air bubbles over the blue-green algae sensor.
- E. Allow readings to stabilize. It should be noted that the readings will not be very stable. Record the before calibration cells/mL reading. Press <Enter> and record the after calibration reading.
- F. Wipe the probes dry with a Kimwipe.

- G. Press <Enter> again and you will be prompted to put in the 2<sup>nd</sup> point.
- H. Using a lab thermometer, take the temperature of the blue-green algae solution. Look up the corresponding blue-green algae value from the temperature/blue-green algae concentration chart. Type this value in as the 2<sup>nd</sup> point and press <Enter>
- I. Check for air bubbles and run wipers if necessary.
- J. Allow readings to stabilize and record blue-green algae concentration. Press <Enter> and record the calibrated blue-green algae concentration.

## VI. CHLOROPHYLL

- A. Prepare 0.5 mg/l Rhodamine WT solution from the stock solution (if needed)
  - a. Retrieve 100mg/l Rhodamine stock solution from refrigerator.
  - b. Warm to room temperature by placing in a warm water bath for 5-10 minutes.
  - c. Rinse clean 1000-ml volumetric flask 3 times with DI water.
  - d. Fill 1000-ml volumetric flask halfway with DI water.
  - e. Rinse 5-ml volumetric pipette once with stock solution. Release rinse into sink ***with water running*** to allow waste to be flushed.
  - f. Pipette exactly 5.0 ml of the stock solution into 1000 ml volumetric flask using a volumetric pipette.
  - g. Dilute 1000 ml flask to the line with DI to form a 0.5 mg/l Rhodamine WT solution. Cap tightly, invert, and swirl several times to homogenize.
  - h. Return stock solution to the refrigerator.
  - i. Rinse all waste in the sink and flush with plenty of water.

**NOTE:** 0.5 mg/l solution is unstable and must be used ***within 24 hours***. Store solution in the dark.
- B. Using the tall calibration cup filled with DI water, place the probes down into the DI water making sure that the temperature probe is submerged.
- C. From the CALIBRATE menu select OPTIC C-CHLOROPHYLL, then CHL UG/L, then 2-POINT. Enter <0> as the first standard.
- D. If necessary, press <3> to engage wipers to remove any air bubbles.
- E. Allow readings to stabilize for at least 24 seconds. Record chlorophyll concentration. Press <Enter> and record the chlorophyll concentration after calibration.
- F. Rinse a clean, dry, tall calibration cup base 3 times with DI water. Fill it ¾ full with the 0.5 mg/l Rhodamine solution.
- G. Using a lab thermometer, note the temperature of the Rhodamine solution.
- H. Wipe the probes off with a Kimwipe. Place them down into the standard, making sure the temperature probe is submerged.
- I. Using the temperature reading obtained in step G, look up corresponding chlorophyll value from the chlorophyll/temperature chart in the folder. Enter this concentration as the second point in the calibration and press <Enter>.
- J. Check for air bubbles and run wipers if necessary
- K. Allow readings to stabilize for at least 24 seconds. Record chlorophyll concentration before calibration. Press <Enter> and record calibrated chlorophyll concentration.

## VII. TURBIDITY

- A. Rinse probes with DI water and place them down into the tall calibration cup filled with DI water.
- B. From the CALIBRATE menu select TURBIDITY. Select 2-POINT and enter <0> as the first standard.
- C. Check for air bubbles and run the wipers if necessary.
- D. Allow readings to stabilize. Record turbidity reading. Press <Enter> and record the calibrated turbidity concentration.

- E. Remove probes from DI water. Dry off probes with a Kimwipe.
- F. Gently fill a clean, dry, tall calibration cup  $\frac{3}{4}$  full with clean 126 NTU solution.
- G. Lower the probes into turbidity solution.
- H. Enter <126> as second standard.
- I. Check for air bubbles and run the wipers if necessary.
- J. Allow readings to stabilize. Record turbidity reading. Press <Enter> and record calibrated turbidity reading.
- K. Some stations will require a second 1-point turbidity calibration to minimize negative turbidity readings in the field. If necessary fill a large glass beaker with DI water. Place a brand new never been field deployed clean probe guard over the probes. Lower the sonde into the bucket.
- L. From the CALIBRATE menu select TURBIDITY, then 1-POINT. Enter the pre-established standard (1.0 for the Gooses surface and bottom, Susquehanna Flats, and Mattawoman Creek).
- M. Allow readings to stabilize. Record the turbidity reading. Press <Enter> and record the calibrated turbidity reading.
- N. Remove the sonde from the beaker.
- O. Now is a good time to remove the small ODO wiper and replace it with the large brush wiper that is used for deployment. The brush wipers are only necessary if there is a tall pH probe on the sonde.

#### VIII. DEPLOYMENT SET-UP

- A. Turn on the following parameters by selecting REPORT from the main menu: Date, Time, Temp, SpCond, Sal, DO%, DOmg/l, Depth, pH, pH mV, Turb, Chl, Fluor, Batt. (Select BGA cells/mL and BGA (RFU) if needed). Return to main menu. Initiate data logging by selecting RUN, then UNATTENDED SAMPLE. Enter INTERVAL (15 minutes), START DATE (Ideally one day before deployment), START TIME, DURATION (365 days), FILE NAME and SITE. The file name will be the 3 letter station code (found on the front of the log book) followed by the last 2 digits of the year and the week number. For example JUG1105 indicates that the file is for Jug Bay, the year 2011, and the 5<sup>th</sup> week of the year. **NOTE:** *Start Time should always be 59 seconds prior to a quarter hour. For example: HH:59:01, HH:14:01, HH:29:01, HH:44:01. Also, some stations (The Gooses and The Profiler) have special instructions for their setup. Please consult the log books for them.*
- B. Record file name, start date/time, sampling interval, free disk space (in kb), and battery life in log book. Make sure stop date is 1 year after start date.
- C. If battery life is less than 45 days, change batteries. If free disk space is less than 100 kb, delete all files by returning to the main menu, selecting FILE, then DELETE ALL FILES. **NOTE:** *You should check to make sure that all files have been successfully uploaded to the server before deleting them.*
- D. Exit menu back to # prompt and disconnect sonde cable.
- E. Screw on waterproof connector cap.
- F. Wrap the top half of the sonde in cling wrap and electrical tape. Label the sonde with the file name.

#### IX. DISSOLVED OXYGEN (Ideally performed day before deployment)

- A. Place probe guard on the sonde and place in a bubbling bucket of water (The bubbler should have been running for at least 2 hours to allow the water to come to full saturation).
- B. Allow the sonde to come to equilibrium (at least 30 minutes).
- C. After enough time has elapsed, select CALIBRATE from the main menu, then OPTIC-O DISSOLVED OXYGEN, then ODOSAT%, then 1-POINT.

- D. Take barometric pressure from the lab barometer and enter the pressure in mmHg at the prompt, and press <Enter>.
- E. Once the readings have stabilized, record the DO mg/L, DO%, barometric pressure, and temperature. Press <Enter> to calibrate. Record the calibrated DO mg/L and DO%.
- F. Return to the main menu. Select ADVANCED, then CAL CONSTANTS. Record ODO Gain. If the gain is outside of the acceptable range it indicates a problem with the probe and it will need to be changed. Leave the sonde in the bubbler until the day of deployment.
- G. If the instrument is going to a site with telemetry, from the ADVANCED menu select SYSTEM and select SAMPLE AND HOLD.

**X. DISSOLVED OXYGEN CHECK (Performed the morning of deployment)**

- A. Verify DO calibration by connection sonde cable to the sonde. From the main menu select FILE, then QUICK VIEW FILE. Note the most recent several samples and check that the readings are stable.
- B. Record the last reading's temperature, DOmg/L, and DO%.
- C. Check the barometric pressure and record the true DO from the temperature/pressure chart.
- D. If samples are consistent and accurate within 0.2mg/L of the true DO value according to the chart, **DO NOT** recalibrate the sonde.
- E. If samples are not within 0.2mg/L of true DO, recalibrate the sonde according to step IX-C through IX-F. You will not need to wait for equilibrium. Record changes on calibration sheet.
- F. If readings are off by greater than 0.5mg/L of true DO, do not recalibrate and do not deploy sonde until the DO issue is resolved.

**POST CALIBRATION**

**XI. NOTES**

- A. During Post Calibration, the idea is to preserve the condition of the sonde after deployment. Thus it is important *not* to clean the sensors or remove any fouling that may have been deposited. However, you may carefully clean the sides of the probes, as long as you preserve the fouling on the actual sensors themselves.
- B. To avoid contamination of the bubbler bucket water it is advised that, before placing a sonde in the bucket, a clean probe guard is placed over the probes. Also the cling wrap should be cut away before placing the sonde in the bucket.
- C. Inspect each probe on the sonde. Using the selections available at the bottom of the Rhodamine calibration chart, give each probe a "fouling grade." This is noted for each probe on the far right of the calibration sheet. If a probe or sonde exhibits particularly severe fouling, you may wish to take a picture of it with the digital camera.
- D. Because most sondes will exhibit biological fouling or sediment buildup on the probes after a deployment, they will tend to contaminate any standards with which they come in contact. Therefore, a second set of dirty standards are used to perform post calibrations.
- E. Clean standards are typically rotated into dirty standards at the end of each field week. When the dirty standards become significantly contaminated with biological material or dirt, they should be discarded and replaced with the clean standards.

**XII. DISSOLVED OXYGEN (ideally performed the day after retrieving meter)**

- A. Place the sonde in the bubbler (The bubbler should have been running for at least 2 hours). The sonde should be in the bubbler for at least 30 minutes. Allow sonde to continue to log data while coming to equilibrium. Connect sonde cable to sonde and access last several readings according to *steps X-A in the Calibration Procedures*. Skip

- to step C
- B. If there was a problem-sonde malfunction, batteries died, etc.-you may run a post calibration by accessing the main menu, selecting RUN, then DISCRETE SAMPLE using a sample interval of 120 seconds.
  - C. Check barometric pressure using the lab barometer.
  - D. Record temperature, barometric pressure, DOmg/L, and DO%. Also record the true DO from the temperature/pressure chart. If the DO is more than 0.5mg/L off from the chart value make a large note on the calibration sheet.
  - E. Use this opportunity to record the depth post calibration also, if applicable.
  - F. Stop logging by selecting RUN, UNATTENDED SAMPLE, and then STOP LOGGING.
  - G. At this time, upload the data from the last deployment. From the main menu select FILE, then QUICK UPLOAD. Select PC6000 and press enter. This will automatically upload the most recent deployment data on to the computer. It will be stored on the C drive in the ECOWWIN folder. Go to the ECOWWIN folder, find the correct file and cut it from the folder. Go to the M drive and find the CON MON folder. From there go to the CONTINUOUS MONITORING folder, then the DATA-WQ folder. Next select the DNR folder. Select the folder with the appropriate year and then the folder with the appropriate month. Paste the file into the folder with the appropriate month (do not paste it into the station folder as this will be done later).
  - H. After uploading the latest file from the instrument, take the instrument out of the bucket. Remove the brush wiper from the DO probe if necessary. This is also a good time to check the probes for fouling and record it on the calibration sheet (see *section XI-C*).
  - I. The meter is now ready to complete the post calibration process, or it can be stored in a calibration cup with DI water until the post calibration can be completed.

### **XIII. SPECIFIC CONDUCTANCE**

- A. Attach an open-ended calibration cup securely to the sonde.
- B. Gently rinse probes 3 times with DI water and 3 times with the conductance standard that was used to calibrate the sonde. Take care not to dislodge fouling from conductance block
- C. Set sonde upright with probes facing up. Fill calibration cup with dirty conductance standard until the standard level is above conductivity block and temperature probe. Pour standard gently down the side of the calibration cup to prevent dislodging dirt or growth from the sensors. If any air bubbles are present in the conductivity block remove them by shaking the meter gently or dislodging them with a pipette.
- D. From the RUN menu select DISCRETE SAMPLE. Make the sampling interval 4 seconds.
- E. While the readings are stabilizing, it is a good time to check the temperature probe. Place a lab thermometer into the solution close to the meter temperature probe. Allow both to stabilize. Record both readings.
- F. Record the conductance readings once they have stabilized. If the readings are out of range make a note on the calibration sheet (a list of acceptable limits can be found in the lab near the calibration stations).

### **XIV. pH**

- A. With calibration cup securely attached to the sonde, gently rinse the probes 3 times with DI water, taking care not to dislodge any fouling from the pH probe.
- B. Gently rinse probes 3 times with pH 7 buffer.
- C. Set sonde upright with probes facing up. Gently pour standard down the side of the calibration cup until the buffer is above the pH and temperature probes.
- D. Allow at least 30 seconds for the sonde to stabilize. When readings have stabilized record pH, pH mV and temperature. Remember to make a note if the readings are out of the

acceptable limits.

- E. Gently rinse probes 3 times with DI water, and then 3 times with pH 10 buffer.
- F. Gently pour pH 10 buffer down the side of the calibration cup until the standard level is above the pH and temperature probes.
- G. Allow at least 30 seconds for the meter to stabilize.
- H. When readings have stabilized record pH, pH mV, and temperature. Calculate the pH slope by subtracting the pH 10 mV from the pH 7 mV.

**XV. CHLOROPHYLL, TURBIDITY, AND BLUE-GREEN ALGAE (if applicable)**

- A. Gently rinse the sides of the probes with DI water, avoiding the optical sensors.
- B. Fill a clean, dry, tall calibration cup  $\frac{3}{4}$  full with DI water.
- C. Place probes down into DI water being sure to submerge the temperature probe.
- D. Make sure the wipers park correctly. If the wipers do not activate themselves press <3> to manually activate them. Note if they wipe correctly and if they park 180° from the sensor.
- E. Allow the readings to stabilize. Record the chlorophyll, turbidity, and blue-green algae readings on the calibration sheet.
- F. Remove probes from DI water and carefully dry probes with a Kimwipe. Do not clean off the optic sensors.
- G. Fill a clean, dry, tall calibration cup  $\frac{3}{4}$  full with the 0.5 mg/L Rhodamine solution (see *section VI-A*). Place probes down into the Rhodamine solution making sure that the temperature probe is submerged.
- H. Run wipers if necessary. Allow readings to stabilize. Record temperature and determine the chlorophyll standard value from the chlorophyll/temperature chart in the log book. Also record the chlorophyll reading from the sonde.
- I. Remove meter from the Rhodamine solution and rinse gently with DI water. Gently wipe off probes with a Kimwipe.
- J. Fill a clean, dry, tall calibration cup  $\frac{3}{4}$  full with dirty 126 NTU turbidity solution.
- K. Lower probes down into calibration cup making sure that the temperature probe is submerged.
- L. Run wipers if necessary. Allow readings to stabilize and record turbidity reading.
- M. There is no second standard for blue-green algae.
- N. You are now finished with the post calibration. Exit out of Ecowatch and remove the sonde cable from the sonde.

***Meter should now be cleaned and stored for next deployment.***

Figure 5 on the following page is an example of a Continuous Monitoring Calibration Sheet.

**Figure 5: Continuous Monitoring Calibration Sheet**

YSI 6600 CALIBRATION LOG	METER _____	Page # _____
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<p><b>CALIBRATION</b></p> <p>Date _____ Time _____</p> <p>Location _____</p> <p>Deployment site: _____ RESET? Y N</p> <p>Initials _____</p> <p>Depth offset _____ Calibrated? Y N Temp Check? _____</p> <p><b>Specific Conductance</b></p> <p>Sp. Cond. Std. _____ <math>\mu\text{S/cm}</math></p> <p>Meter reads _____ <math>\mu\text{S/cm}</math></p> <p>changed to _____ <math>\mu\text{S/cm}</math></p> <p>Cond. Cell Const. _____ (Range 4.6 - 5.45)</p> <p><b>pH 7</b></p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Meter pH reads _____ <math>\rightarrow</math> _____</p> <p>pH mV _____ mV (Range 0 <math>\pm</math> 50)</p> <p><b>pH 10</b></p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Meter pH _____ <math>\rightarrow</math> _____</p> <p>pH mV _____ mV (Range -180 <math>\pm</math> 50 )</p> <p>Slope (pH7 mV - pH10 mV) _____ (Range 165 - 180 )</p> <p><b>Chlorophyll (2-point)</b></p> <p>Chlorophyll zero _____ <math>\rightarrow</math> _____ <math>\mu\text{g/L}</math></p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Rhodo WT equivalent _____ <math>\mu\text{g/L}</math></p> <p>Meter reads _____ <math>\rightarrow</math> _____ <math>\mu\text{g/L}</math></p> <p>Wiper parks 180 deg. from sensor? YES NO</p> <p><b>Turbidity (2-point)</b></p> <p>Turb zero _____ <math>\rightarrow</math> _____ NTU</p> <p>Turb Std _____ NTU</p> <p>Meter reads _____ <math>\rightarrow</math> _____ NTU</p> <p>Wiper parks 180 deg. from sensor? YES NO</p> <p><b>BGA (2-point)</b></p> <p>BGA zero _____ <math>\rightarrow</math> _____ cells/mL</p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Rhodo WT equivalent _____ cells/mL</p> <p>Meter reads _____ <math>\rightarrow</math> _____ cells/mL</p> <p>Wiper parks 180 deg. from sensor? YES NO</p> <p><b>Dissolved Oxygen</b></p> <p>Temperature _____ <math>^{\circ}\text{C}</math> Wiper? YES NO</p> <p>Bar. Pressure _____ mm Hg</p> <p>Chart D.O. _____ mg/L</p> <p>Meter D.O. _____ <math>\rightarrow</math> _____ mg/L</p> <p>D.O. Saturation _____ % <math>\rightarrow</math> _____ %</p> <p>D.O. Gain _____ (Range 0.8 - 1.7)</p> <p><b>PROGRAMMING</b></p> <p>Parameters: (circle) Date Time Temp SpC Sal DO% DO pH</p> <p>Set time to: _____ : _____ EST pH mV Turb Chl Fluor</p> <p>Log to filename _____ Batt Depth</p> <p>Start Date / Time / interval _____ / _____ / _____ min</p> <p>Started Logging YES NO</p> <p>Free Disk Space _____ kb (delete if &lt; 100kb)</p> <p>Battery Life/Volts _____ / _____ changed Y N</p> <p>(change if batt life &lt; 45 days)</p> <p><b>Field/Cal Notes</b></p> <p><b>DO Check</b></p> <p>_____/_____/_____ :_____</p> <p>Temp _____</p> <p>B.P. _____</p> <p>Chart _____</p> <p>Meter _____</p> <p>DO % _____</p> <p>Re-Cal? Y N</p> <p>Batt Check _____</p> <p>Changed Y N</p>	<p><b>POST CALIBRATION</b></p> <p>Date _____ Time _____</p> <p>Location _____</p> <p>Initials _____</p> <p>Depth Offset _____ Depth _____</p> <p>Stopped Logging? YES NO Upload? YES NO</p> <p><b>Specific Conductance</b></p> <p>Sp. Cond. Std. _____ <math>\mu\text{S/cm}</math> Fouling Grade _____</p> <p>Meter reads _____ <math>\mu\text{S/cm}</math></p> <p><b>Temperature</b></p> <p>Thermometer temp _____ <math>^{\circ}\text{C}</math> YSI temp: _____ <math>^{\circ}\text{C}</math></p> <p><b>pH 7</b></p> <p>Temperature _____ <math>^{\circ}\text{C}</math> Fouling Grade _____</p> <p>Meter pH _____</p> <p>pH mV _____ mV</p> <p><b>pH 10</b></p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Meter pH _____</p> <p>pH mV _____ mV</p> <p>Slope _____</p> <p><b>Chlorophyll (2-point)</b></p> <p>Chlorophyll zero _____ <math>\mu\text{g/L}</math> Fouling Grade _____</p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Chlorophyll Std _____ <math>\mu\text{g/L}</math></p> <p>Meter reads _____ <math>\mu\text{g/L}</math></p> <p>Wiper parks 180 deg. from sensor? YES NO</p> <p><b>Turbidity (2-point)</b></p> <p>Turb zero _____ NTU Fouling Grade _____</p> <p>Turb Std _____ NTU</p> <p>Meter reads _____ NTU</p> <p>Wiper parks 180 deg. from sensor? YES NO</p> <p><b>BGA (2-point)</b></p> <p>BGA zero _____ cells/mL Fouling Grade _____</p> <p>Temperature _____ <math>^{\circ}\text{C}</math></p> <p>Rhodo WT equivalent _____ cells/mL</p> <p>Meter reads _____ cells/mL</p> <p>Wiper parks 180 deg. from sensor? YES NO</p> <p><b>Dissolved Oxygen</b> Notes</p> <p>Temperature _____ <math>^{\circ}\text{C}</math> Fouling Grade _____</p> <p>Bar. Pressure _____ mm Hg</p> <p>Chart D.O. _____ mg/L</p> <p>Meter D.O. _____ mg/L</p> <p>D.O. Saturation _____ %</p> <p>Wiper? YES NO</p> <p><b>Battery</b> changed YES NO</p> <p><b>DATA SET COMPARISON</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>old</th> <th>new</th> <th>Discrete</th> <th>Initials:</th> </tr> </thead> <tbody> <tr><td>meter</td><td></td><td></td><td></td><td></td></tr> <tr><td>time</td><td></td><td></td><td></td><td></td></tr> <tr><td>Temp.</td><td></td><td></td><td></td><td><math>^{\circ}\text{C}</math></td></tr> <tr><td>Sp. Cond</td><td></td><td></td><td></td><td><math>\mu\text{S/cm}</math></td></tr> <tr><td>Salinity</td><td></td><td></td><td></td><td>ppt</td></tr> <tr><td>D.O.</td><td></td><td></td><td></td><td>mg/l</td></tr> <tr><td>pH</td><td></td><td></td><td></td><td></td></tr> <tr><td>Turb.</td><td></td><td></td><td></td><td>NTU</td></tr> <tr><td>Chloro</td><td></td><td></td><td></td><td><math>\mu\text{g/L}</math></td></tr> <tr><td>total depth =</td><td>_____ m</td><td>_____ m</td><td>_____ m</td><td>_____ m</td></tr> <tr><td>sample depth =</td><td>_____ m</td><td></td><td></td><td></td></tr> </tbody> </table>		old	new	Discrete	Initials:	meter					time					Temp.				$^{\circ}\text{C}$	Sp. Cond				$\mu\text{S/cm}$	Salinity				ppt	D.O.				mg/l	pH					Turb.				NTU	Chloro				$\mu\text{g/L}$	total depth =	_____ m	_____ m	_____ m	_____ m	sample depth =	_____ m			
	old	new	Discrete	Initials:																																																									
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Salinity				ppt																																																									
D.O.				mg/l																																																									
pH																																																													
Turb.				NTU																																																									
Chloro				$\mu\text{g/L}$																																																									
total depth =	_____ m	_____ m	_____ m	_____ m																																																									
sample depth =	_____ m																																																												

## Appendix 6. YSI 6600/V2 Calibration, Daily Check, and Post-Calibration Procedures (Water Quality Mapping)

J. Strong

Revised: April 2017

### Calibration

#### 1. SETUP

- A. Remove waterproof cap from the 9-pin sonde connector and attach sonde cable from laptop to the sonde.
- B. Take a spare Hydrolab battery and attach it to the connector on the laptop.
- C. Launch “Ecowatch” and select the sonde icon  from the TOOLBAR menu.
- D. Choose *COM 1* (or sometimes *COM 4* depending on which laptop you use) when prompted to select COM port then press <Enter>.
- E. Type **menu** at the # prompt and select *SYSTEM*.
- F. Select *Date & Time*, then select *Time*.
- G. From a **reliable** time source, such as the radio controlled clock or the phone operator, enter correct time of day in **Eastern Standard Time**, then press <Enter> simultaneously with correct time. Time has now been set.
- H. Return to the main menu by pressing <Esc>.
- I. Next select *Report*.
- J. Select **the following** parameters **prior to calibration**:
  - Time, Temp C, SpCond mS/cm, Sal ppt, pH, pH mV,
  - Turbidity NTU, Chl ug/L, Chl RFU, ODO Sat%, ODO mg/l,
  - Battery volts.
- K. Press Esc until you are back to the main menu.

**Note:** If sonde is to be used on the R/V Kerhin, you **MUST** set it up to log data. To do this, **AFTER** calibrating sonde return to main menu. Initiate data logging by selecting RUN, then UNATTENDED SAMPLE. Enter INTERVAL (4 seconds), START DATE (Ideally day of cruise), START TIME (IDEALLY 2 HOURS BEFORE CRUISE BEGINS), DURATION (2 days), FILE NAME and SITE. The file name will be the 3 letter segment code followed by mmyy. For example, for segment CB4 in April 2017 would be CB40417.

If battery life is less than 45 days, change batteries. If free disk space is less than 100 kb, delete all files by returning to the main menu, selecting FILE, then DELETE ALL FILES.

#### 2. Dissolved Oxygen

- A. Fill a clean 5 gallon bucket 2/3 full with tap water. Sparge the water with an aquarium pump and air-stone for at least two hours prior to calibration,
- B. Remove calibration cup from sonde and inspect ODO probe to ensure that the optical sensor is free of scratches, chips, or other major damage.
- C. Place a YSI probe guard onto sonde.
- D. Place sonde into the 5 gallon bucket for at least 30 minutes before calibrating.

Make sure that the ODO probe and temperature probe are fully submerged. Position sonde in bucket so that the air bubbles do not contact probes.

- E. From the main menu, select *CALIBRATE* then *OPTIC-O DISSOLVED OXY*.
- F. Next choose *ODO SAT%* then *ONE POINT*. Take current Barometric Pressure from a reliable barometer in the room. Log in Barometric Pressure in mmHg and press <Enter>.
- G. Allow ODO% to stabilize for at least 30 seconds. Record temperature, barometric pressure, chart DO value (obtained from pressure/temperature chart), meter ODO mg/l and ODO Sat%. Press <Enter> and record adjusted ODO mg/l and ODO Sat%. Press <Enter>.
- H. Return to the Calibrate menu by pressing <Esc>.

### 3. Chlorophyll

- A. Prepare 0.5 mg/l Rhodamine WT solution from stock solution.
  - 1) Retrieve 100 mg/l Rhodamine stock solution from refrigerator.
  - 2) Allow stock solution to reach ambient temperature using a warm water bath
  - 3) Rinse clean 1000-ml volumetric flask 3 times with DI.
  - 4) Fill 1000-ml volumetric flask halfway with DI water.
  - 5) Using a volumetric pipette, pipette exactly 5.0 ml of the stock solution into 1000 ml volumetric flask
  - 6) Bring 1000 ml flask to the line with DI to form a 0.5 mg/l Rhodamine WT solution. Cap tightly, invert and swirl several times to homogenize.
- B. Fill a clean calibration cup (the taller one) with **black top** attached 3/4 full with DI water. Remove probe guard and place probes down into DI water allowing at least three inches between probes and the bottom of the calibration cup.
- C. Select *OPTIC C - CHLOROPHYLL*, from the Calibrate menu, then *CHL UG/L*, then *TWO POINT*. Enter "0" as the first standard. Press <Enter>.
- D. Check optics for air bubbles. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
- E. Allow readings to stabilize and record chlorophyll blank concentration. Press <Enter>, and record calibrated chlorophyll blank concentration. Press <Enter> again.
- F. Rinse calibration cup (the taller one) 3 times with Rhodamine solution, then fill cup 3/4 full with the 0.5 mg/l Rhodamine solution.
- G. Using lab thermometer, record temperature of Rhodamine standard in the calibration cup.
- H. Dry probes with Kimwipes then place probes down into Rhodamine standard allowing at least three inches between probes and the bottom of calibration cup.
- I. Using temperature reading obtained in step G, look up corresponding Chlorophyll value from Chlorophyll/Temperature chart in the folder. Enter this concentration (e.g. 22°C = 113ug/l) as the second point in the calibration and press <Enter>.
- J. Check for air bubbles over optics. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
- K. Allow readings to stabilize. Record chlorophyll concentration and temperature. Press <Enter> and record calibrated chlorophyll concentration. Press <Enter> again.
- L. Return to the Calibrate menu by pressing <Esc>.

#### 4. Turbidity

- A. Fill a clean calibration cup (the taller one) with **black top** attached 3/4 full with DI water.
- B. Rinse probes with DI and place probes down into calibration cup allowing at least three inches between probes and the bottom of the calibration cup.
- C. From the Calibrate menu select *TURBIDITY*, then *2 POINT*.
- D. Enter the first standard as “0”. Press <Enter>.
- E. Check for air bubbles over optics. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
- F. Allow readings to stabilize. Record turbidity concentration. Press <Enter> and record calibrated turbidity concentration. Press <Enter> again.
- G. Remove probes from calibration cup and dry off all probes with a Kimwipe. This will prevent the turbidity standard from becoming diluted.
- H. Fill a **clean, dry** calibration cup (the taller one) with **black top** attached 3/4 full with clean 126 NTU solution. Carefully pour the solution down the inner wall of the calibration cup to minimize any air bubbles.
- I. Place probes down into calibration cup allowing at least three inches between probes and the bottom of the calibration cup.
- J. Enter second standard as 126. Press <Enter>.
- K. Check for air bubbles over optics. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
- L. Allow readings to stabilize. Record turbidity concentration. Press <Enter> and record calibrated turbidity concentration. Press <Enter> again.
- M. Return to the Calibrate menu by pressing <Esc>.

#### 5. Specific Conductance

- A. Attach open-ended calibration cup securely to sonde and rinse probes 3 times with DI water.
- B. Rinse probes 3 times with specific conductance standard 12900 $\mu$ S/cm.
- C. Set meter upright with probes facing up. Gently swirl clean 12900 $\mu$ S/cm standard and fill calibration cup until the standard level is above all of the probes. If any air bubbles are apparent in the conductivity block, remove them by shaking meter gently or dislodging them with a cotton swab.
- D. Select *CONDUCTIVITY*, then *SP COND* from the Calibrate menu.
- E. Enter the conductance of the standard **in mS/cm**.  
Ex: 12900  $\mu$ S/cm = 12.90 mS/cm. Press <Enter>.
- F. Allow readings to stabilize. Record specific conductance reading in  $\mu$ S/cm and press <Enter>.
- G. Record calibrated specific conductance reading in  $\mu$ S/cm. Press <Enter> again.
- H. Return to Calibrate menu by pressing <Esc>.

#### 6. pH

- A. With calibration cup securely attached to meter, rinse probes 3 times with DI water.
- B. Rinse probes 3 times with pH 7 buffer.
- C. Set meter upright with probes facing up. Fill calibration cup with **clean** pH 7 standard.
- D. Select *PH* from the calibrate menu, then *2-POINT*.
- E. Enter “7” as the 1<sup>st</sup> point and press <Enter>. Allow at least 60 seconds for meter to stabilize. If readings fail to stabilize, try unplugging the laptop from the

- power source and pull YSI stand away from the wall.
- F. When readings have stabilized record temperature and pH reading. Press <Enter> and record calibrated *pH* and *pH/mV* reading. Press <Enter>.
- G. Rinse probes 3 times with DI water. Then rinse 3 times with pH 10 buffer.
- H. Fill the calibration cup with **clean** pH 10 buffer.
- I. Enter 10 as the 2<sup>nd</sup> point and press <Enter>, allow at least 60 seconds for meter to stabilize.
- J. When readings have stabilized record temperature and pH reading. Press <Enter>, record calibrated *pH* and *pH/mV* reading. Press <Enter>.
- K. Return to the Main menu by pressing <Esc>
- L. Select *Report*, then unmark *pH/mV* by pressing “C”.
- M. Press <Esc> until asked to *Exit menu (Y/N)?*, then press “Y”.

## DAILY CHECK

**Day before each run:** Set up YSI V2 to be checked the following morning by rinsing probes with DI. Place probe guard onto YSI V2 and place in a clean 5 gallon bucket filled 2/3 full with tap water, with submerged airstone and air pump running. Position sonde in the bucket so that the air bubbles do not contact probes.

### Morning of run:

- A. Take a spare Hydrolab battery and attach it to the connector on the laptop.
- B. Attach sonde cable to sonde in 5 gallon bucket and launch *Ecowatch* as you would to calibrate.
- D. Type "menu" at the # prompt, then select *Report*.
- E. **MAKE SURE THAT ONLY THE FOLLOWING PARAMETERS ARE CHECKED UNDER THE REPORT MENU:**  
-Time, Temp C, SpCond. mS/cm, Sal ppt, pH, Turb., Chl ug/L, Chl RFU, ODOsat %, ODO mg/L, and Battery volts.
- F. Return to the Main menu by pressing <Esc> and select *Run*, then *Discrete Sampling*, then *Start Sampling*.
- G. Allow readings to stabilize for at least 30 seconds. Record Temperature, Barometric Pressure, Chart DO mg/L (from pressure/temperature chart), meter ODO mg/l, and ODO% Saturation.  
Refer to “Ranges for Daily Check” page if meter ODO is off by +/- 0.2mg/L from chart DO. Remove sonde from bucket and remove probe guard.
- H. Fill a clean calibration cup (the taller one) with **black top** attached 3/4 full with DI water.
- I. Place probes down into calibration cup allowing at least three inches between probes and the bottom of the calibration cup.
- J. Check optics for air bubbles. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
- K. Record Chlorophyll and Turbidity "0" once readings have stabilized. If Chlorophyll “0” is off by 1µg/L or if Turbidity “0” is off by 2 NTU, re-calibrate using the procedures listed in the Calibration section.
- L. Attach a clean, dry open-ended calibration cup to the sonde. Rinse calibration cup and probes three times with clean 12900µS/cm specific conductance standard. Place sonde in ring stand with probes facing up. Fill calibration cup with clean 12900µS/cm specific conductance standard. Wait for meter to stabilize and record specific conductance reading. Re-calibrate specific conductance if meter is off by +/- 645µS/cm.
- M. Rinse probes three times with DI then three times with pH 7 buffer.
- N. Pour clean pH 7 buffer into calibration cup, wait until readings stabilize, then record

temperature and pH 7 reading. If readings fail to stabilize, try unplugging the laptop from the power source and pull YSI stand away from the wall.

- O. Rinse probes three times with DI then three times with pH 10 buffer.
- P. Pour clean pH 10 buffer into calibration cup, wait until readings stabilize, then record temperature and pH 10 reading.
- Q. Recalibrate pH 7 and pH 10 if either value is off by +/- .2 units

## POST CALIBRATION

- A. Set YSI V2 up like you would for “*Day before each run*” procedure in Daily Check section. Place sonde into the 5 gallon bucket for at least 30 minutes before post calibrating.
- B. Remove waterproof cap from the 9-pin sonde connector and attach sonde cable from laptop to the sonde.
- C. Take a spare Hydrolab battery and attach it to the connector on the laptop.
- D. Launch “Ecowatch” and select the sonde icon  from the TOOLBAR menu.
- E. Choose *COM 1* (or sometimes *COM 4* depending on which laptop you use) when prompted to select COM port then press <Enter>.
- F. Type **menu** at the # prompt and select *REPORT*.
- G. Select **the following** parameters to be post calibrated:
  - **Time, Temp C, SpCond mS/cm, Sal ppt, pH, pH mV, Turbidity NTU, Chl ug/L, Chl RFU, ODO Sat%, ODO mg/l, Battery volts.**
- H. Return to the Main menu by pressing <Esc> and select *Run*, then *Discrete Sampling*, then *Start Sampling*.

### 1) Dissolved Oxygen

- A. Allow ODO% to stabilize for at least 30 seconds. Record temperature, barometric pressure, chart DO value (obtained from pressure/temperature chart), meter ODO mg/l and ODO Sat%.
- B. Remove sonde from bucket and remove probe guard.

### 2) Chlorophyll and Turbidity

- A. Fill a tall clean **black top** calibration cup  $\frac{3}{4}$  full with DI water. Place probes down into DI water allowing at least three inches between probes and the bottom of the cup.
- B. Check optics for air bubbles. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone. Allow readings to stabilize. Record chlorophyll and turbidity "0" value.
- C. Rinse calibration cup 3 times with 0.5 mg/l Rhodamine WT solution (obtained from step 3A in the Calibration procedure), then fill a tall clean cup  $\frac{3}{4}$  full with the 0.5 mg/l Rhodamine solution.
- D. Wipe probes dry with a Kimwipe. Place probes down into Rhodamine standard allowing at least three inches between probes and the bottom of calibration cup.
- E. Check optics for air bubbles. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
- F. Record Chlorophyll value, temperature, and Rhodamine equivalent value (obtained from Chlorophyll/Temperature chart in folder) after readings have

- stabilized.
- G. Remove sonde from calibration cup, rinse probes with DI and dry all probes with a Kimwipe. Fill a clean, tall, dry calibration cup with black top  $\frac{3}{4}$  full with 126 NTU standard.
  - H. Place probes down into Turbidity standard allowing at least three inches between probes and the bottom of the cup.
  - I. Check optics for air bubbles. If air bubbles exist, **gently** raise the sonde up and down in the solution until air bubbles are gone.
  - J. Record Turbidity value after readings have stabilized.

### 3) Specific Conductance

- A. Attach open-ended calibration cup securely to sonde.
- B. Rinse probes 3 times with DI then 3 times with 12900 $\mu$ S/cm conductance standard.
- C. Set meter upright with probes facing up. Fill calibration cup with clean 12900 $\mu$ S/cm conductance standard until the standard level is above conductivity block and temperature probe. If any air bubbles are apparent in the conductivity block, remove them by shaking meter gently or dislodging them with a cotton swab.
- D. Record specific conductance when readings have stabilized.

### 4) pH

- A. With calibration cup securely attached to sonde, rinse probes 3 times with DI water.
- B. Rinse probes 3 times with pH 7 buffer.
- C. Set meter upright with probes facing up. Pour **clean** pH 7 standard into the calibration cup until the buffer level is above pH and temperature probes.
- D. Allow at least 60 seconds for meter to stabilize. If readings fail to stabilize, try unplugging the laptop from the laptop from power source and pull YSI stand away from the wall.
- E. When readings have stabilized, record pH, pH mV and temperature.
- F. Rinse probes 3 times with DI water then 3 times with pH 10 buffer.
- G. Pour **clean** pH 10 standard into calibration cup until the standard level is above pH and temperature probes.
- H. Allow at least 60 seconds for meter to stabilize.
- I. When readings have stabilized, record pH, pH mV and temperature.
- J. Return to the Main menu by pressing <Esc>
- K. Select *Report*, then unmark pH/mV by pressing “C”.
- L. Press <Esc> until asked to *Exit menu (Y/N)?*, then press “Y”.

### 5) **Downloading data from sonde after R/V Kerhin method is used. R/V Kerhin method ONLY**

- A. Stop logging by selecting RUN, UNATTENDED SAMPLE, and then STOP LOGGING.
- B. At this time, upload the data from the last cruise. From the main menu select FILE, then QUICK UPLOAD. Select PC6000 and press enter. This will automatically upload the most recent cruise data on to the computer. It will be stored on the C drive in the ECOWWIN folder. Go to the ECOWWIN folder, find the correct file and cut it from the folder. Go to the M drive and

find the DATAFLOW folder. From there go to the RAW folder, then the YEAR. Next select the folder that corresponds to the cruise done. Paste the file into the folder. A copy of the vessel navigation file is also placed in the raw folder.

Figure 6 on the following page is an example of a Water Quality Mapping calibration sheet.

Figure 6: Water Quality Mapping Calibration Sheet

Date					
Time					
Calibration Type: Cal, Post, Check					
River/Area Being Tested					
Set Time?	Yes	No	Yes	No	Yes
Initials					
<b>DISSOLVED OXYGEN (mg/L)</b>					
Temperature: °C					
Bar. Pressure: mmHg					
Chart D.O.: mg/L					
Meter D.O.: mg/L					
-Adjusted to: mg/L					
D.O. Saturation : %					
-Adjusted to:					
<b>CHLOROPHYLL (µg/L)</b>					
Chlorophyll zero: µg/L					
-Adjusted to: µg/L					
Temperature: °C					
Rhodo WT equivalent: µg/L					
Meter Reads: µg/L					
-Adjusted to: µg/L					
<b>TURBIDITY (NTU)</b>					
Turbidity zero:					
-Adjusted to:					
Turbidity standard:	126	126	126	126	126
Meter Reads:					
-Adjusted to:					
<b>SPECIFIC CONDUCTANCE (µS/cm)</b>					
Sp. Cond. Std.: µS/cm	12,900	12,900	12,900	12,900	12,900
Meter Reads: µS/cm					
-Adjusted to: µS/cm					
<b>pH 7</b>					
Temperature: °C					
Meter Reads:					
-Adjusted to:					
pH mV: (-50 to 50 )					
<b>pH 10</b>					
Temperature: °C					
Meter Reads:					
-Adjusted to:					
pH mV: (-230 to -130)					
Notes:					

**Appendix 7. Continuous Monitoring and Water Quality Mapping Filtering Methods**  
(Revised May 2009)

**A. PARTICULATE SAMPLE FILTRATION, PROCESSING AND STORAGE**

**1. Chlorophyll**

Chlorophyll samples are filtered in the same manner for all programs.

- a) For every depth sampled, clean a 47mm bell with deionized (DI) water. Set up unit for filtering. Be sure that there is a trap in line between the manifold and the vacuum source.
- b) Place a Whatman 47mm GF/F glass fiber filter pad (pore size = 0.7  $\mu$ m) on the filter frit. Always use clean forceps when handling the filter pads.
- c) Mix sample thoroughly by agitating and shaking the sample bottle vigorously, then rinse graduated cylinder three times with sample.
- d) Agitate the sample again before measuring in the graduated cylinder. Fill graduated cylinder with sample and filter desired volume through filtration unit. Be sure to use a graduate that is close to the volume being filtered (ex: if you are only filtering 80 ml of sample use a 100 ml graduate). Keep the vacuum pressure below 10 inches of Hg (around 8" Hg is good).
- e) Filter sufficient volume of sample (50 - 1500 ml) to solidly color the filter pad.
- f) Record the total volume filtered on the foil square.
- g) Agitate the squirt bottle of  $MgCO_3$ , as it settles rapidly. Add approximately 1 ml of  $MgCO_3$  suspension (1.0 g  $MgCO_3$  in 100 ml of DI water) to the last 25 ml of sample in the filtration bell.

*NOTE: Samples for dissolved parameters are not to be collected from this filtrate.*

- h) Using forceps (1 or 2 pair), fold filter in half with sample inside and remove filter pad.
- i) Place pad in pre-marked foil square, and carefully fold foil square in thirds, horizontally. Then fold the ends in to seal the filter inside. Be sure forceps do not touch sample residue on the filter pads, because the sample will adhere to the forceps.
- j) Be sure that foil square is marked with date, station, depth of sample, volume of sample filtered, and sample number.
- k) Place foil packet into zip-lock plastic bag or pad container. When sampling on the small boats or a land run place the foils in a bag or pad container in the ice chest and place them in the appropriately labeled bag in the Field Office freezer when you return to the office. The bags for the chlorophyll samples go in the bin marked CBL in the freezer.
- l) Record sample station number, date, volume filtered (L), depth (m), layer, start time, end time and field scientist sign-off on the chlorophyll volume sheet. Record the study code, submitter code, data category code and replicate number, if not already pre-filled in, on chlorophyll volume sheet. This sheet is submitted to the laboratory with the samples. When you return the samples to the Field Office freezer, place the volume sheet in the rack on the side of the freezer marked "Chlorophyll, CBL".

*NOTE: The filter pads for chlorophyll samples should be exposed to as little direct sunlight as possible. Store as soon as possible.*

## 2. Particulate Carbon/ Particulate Nitrogen (PC/PN)

PC/PN samples are filtered in the same manner for all programs.

- a) Follow steps A.1.a. through A.1.d. above setting up two 25 mm filter bells using two pre-combusted 25 mm GF/F filters (pore size = 0.7  $\mu$ m). The PC/PN pads come from CBL.
- b) Filter 10-200 ml through each filter. Filter enough sample to leave noticeable color on the filter pad.
- c) Make sure filter is sucked dry and the same volume is filtered for both pads.
- d) Record the volume filtered (total volume through one pad - do not add the volumes for the 2 pads together) on the foil square.

*NOTE: Samples for dissolved parameters are not to be collected from this filtrate.*

- e) Using forceps, fold each filter in half.
- f) Place both filters in a foil square labeled with date, CBL sample number, station, sample layer, PC/PN, and volume filtered. Be sure that the pads are not overlapping in the foil square to keep them from freezing together.
- g) Fold the foil square as described in step A.1.i. above and then place folded foil in zip-lock bag or pad container, and put in the freezer (large boats) or in a cooler on ice (small boats & land).
- h) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".

## 3. Particulate Phosphorus/ Particulate Inorganic Phosphorus (PP/PIP)

- a) Follow steps A.1.a. through A.1.d. above setting up and rinsing two 47 mm filter bells and flasks. The filters used are two Whatman 47 mm GF/F filters (same pads we use for chlorophyll). These filters are Pre-Combusted and are received from CBL.
- b) Filter 50 ml of sample through each filter pad.
- c) Use the filtrate as an equipment rinse and discard.
- d) Then filter enough additional (another 50 - 450 ml) to leave a noticeable color on the filter pad.
- e) Record the total volume filtered through each pad being sure to add the 50 ml rinse water (total volume through one pad – do not add the volumes for the 2 pads together) on the foil square.
- f) Use this filtrate to fill up the tubes for the dissolved parameter analysis. See section B (Filtered dissolved nutrient sample collection) below.
- g) After collecting filtrate, make sure filter is sucked dry.
- h) Rinse the filter pad using at least three - 10 ml rinses of DI water, sucking the pad dry after each rinse.
- i) Using forceps, fold each filter in half.
- j) Place both filters in a foil square labeled with date, PP/PIP, CBL sample number, station, sample layer, and volume filtered (this is the total volume of sample through each pad, including the initial 50 ml rinse). Be sure that the pads are not overlapping in the foil square to keep them from freezing together.
- k) Fold the foil square as described in step A.1.i. above. Place foil square in zip-lock bag or pad container, and put in the cooler on ice until you return to the field office.
- l) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".

#### 4. Total Suspended Solids/ Volatile Suspended Solids (TSS/VSS)

The instructions below apply to samples processed for TSS/VSS for Dataflow and Continuous Monitoring programs.

- a) Follow steps A.1.a. through A.1.d. above setting up and rinsing one 47 mm filter bell and flask. The filter used is a pre-combusted and pre-weighed 47 mm GF/F filters (pore size = 0.7  $\mu\text{m}$ ). The VSS pads come in individually numbered petri dishes from CBL. Remove one pad from its individual petri dish and place on the filter screen. Record the pad number from the petri dish on the TSS/VSS foil label in the space marked "Pad #".
- b) Filter 50 - 500 ml and filter through the filter pad leaving a noticeable color on the pad.
- c) Make sure filter is sucked dry and rinse the filter pad using at least three - 10 ml rinses of DI water, sucking the pad dry after each rinse. If the sample is very salty (e.g. Lower Chesapeake, Coastal Bays) you should rinse an extra 1-2 times.
- d) Using forceps, fold the filter in half. Place the filter in a foil square labeled with date, TSS/VSS, CBL sample number, station, sample layer, volume filtered, and VSS pad number.
- e) Fold the foil square as described in step A.1.i. above. Place foil square in zip-lock bag or pad container, and put in the cooler on ice until you return to the field office.
- f) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".

#### 5. Total Suspended Solids (TSS) Only

The instructions below apply to samples processed for TSS only for Dataflow and Continuous Monitoring programs.

- a) Follow steps A.1.a. through A.1.d. above setting up and rinsing one 47 mm filter bell and flask. The filter used is a pre-weighed 47 mm GF/F filters (pore size = 0.7  $\mu\text{m}$ ). The TSS pads are individually numbered from CBL. Remove one pad from the petri dish pad container and place on the filter screen numbered side down (this will allow number to be visible when pad is folded after filtering).
- b) Filter 50 - 500 ml and filter through the filter pad leaving a noticeable color on the pad.
- c) Make sure filter is sucked dry and rinse the filter pad using at least three - 10 ml rinses of DI water, sucking the pad dry after each rinse. If the sample is very salty (e.g. Lower Chesapeake, Coastal Bays) you should rinse an extra 1-2 times.
- d) Using forceps, fold the filter in half. Place the filter in a foil square labeled with date, TSS, CBL sample number, station, sample layer, and volume filtered.
- e) Fold the foil square as described in step A.1.i. above. Place foil square in zip-lock bag or pad container, and put in the cooler on ice until you return to the field office.
- f) Upon return to the Field Office, place the foils in their appropriate zip-lock bag in the sample freezer and place the bag in the CBL bin. Put the completed CBL volume sheet in the rack on the side of the freezer marked "CBL".

## B. DISSOLVED NUTRIENT SAMPLE FILTRATION & COLLECTION

*NOTE: The filtrate collected for this sample must come from either the TSS/VSS or PP/PIP filtration set-up. If you cannot get enough water through these pads to fill all tubes, then use plain GF/F filters to get enough filtrate. The filtrate may not come from pads that are in contact with  $\text{MgCO}_3$  (CHLA).*

1. The following steps are to be completed for collection of all filtrate for the samples below:
  - a) Run 50 ml of sample water through the filter.
  - b) Use this 50 ml of filtrate to rinse the flask and then discard.

c) Run more sample water through the filter and collect in the flask.

**2. Total Dissolved Nitrogen & Phosphorus (TDN/TDP)**

- a) Rinse the TDN/P tube (30 ml borosilicate glass – tall skinny tube!) and cap three times with filtrate.
- b) Flick all remaining water droplets out of the test tube and cap.
- c) Rinse the 10 ml graduated cylinder three times with filtrate.
- d) Fill the graduated cylinder with 10 ml of filtrate.
- e) Carefully, pour the 10 ml of filtrate into the test tube and cap tightly.
- f) Store the test tube in the freezer.
- g) If on a land run or small boat, store the tubes on ice in a cooler and place in the Field Office freezer when you return from the field.

**3. Nitrate, Nitrite, Ammonia, Orthophosphate**

- a) Rinse the 3 like-numbered AA vials (4 ml polystyrene cups) and 3 caps three times with filtrate.
- b) Fill the AA vials with filtrate up to ridge where the caps are seated.
- c) Snap the caps on the vials. You should hear them snap twice to be fully seated.
- d) Store 3 AA vials in the freezer.
- e) If on a land run or small boat, store the tubes on ice in a cooler and place in the Field Office freezer and refrigerator when you return from the field.

**C. QUALITY CONTROL SAMPLES (IF APPLICABLE)**

**1. Clean Check**

The clean check is a two-step process. First, clean, dry pads are analyzed as if they had been in contact with actual samples. Second, deionized water is filtered through a second set of pads in place of sample water.

- a) Place clean, dry pads in foils for appropriate parameters to be analyzed as if they had been used for real samples.
- b) Performed the same as A – C above, however, only deionized (DI) water is used. The volume filtered should be consistent with other volumes filtered on the run the clean check is being performed on.

## Appendix 8. Continuous Monitoring Parameters

C. Trumbauer, C. Heyer, M. Trice  
Revised: 5/29/2007

Parameter	Format/Units	Field Name	Method Code
Date	mmddyyyy	SAMPLE_DATE	
Time	hh:mm:ss (24 hr clock – EST)	SAMPLE_TIME	
Station		STATION	
Tributary		WATER_BODY	
Segment		CBSEG_2003	
Sonde (YSI Sonde Name)	Variable Length (e.g. “Gina” or Serial Number)	SONDE	
Latitude	Decimal Degrees (NAD83)	LATITUDE	
Longitude	Decimal Degrees (NAD83)	LONGITUDE	
Sample Depth Value	meters (+)	SAMPLE_DEPTH*	
Sample Depth Reference	BS = Floating Below Surface B = Bottom*** S = Surface ***	LAYER_CODE*	
Water Column Depth	meters (+)	TOTAL_DEPTH**	
Battery Voltage	Volts	BATT	
Water Temperature	°C	WTEMP	F01
Specific Conductance	ms/cm	SPCOND	
Salinity (From YSI Sonde)	Ppt	SALINITY	F01
Dissolved Oxygen Saturation	%	DO_SAT	F02
Dissolved Oxygen Concentration	mg/l	DO	F02
pH	Su	PH	F01
Turbidity	NTU or FNU	TURB_NTU	F01
Fluorescence	% FS (FS = Full Scale)	FLUOR	
Pre-calibrated Total Chlorophyll	µg/l	TCHL_PRE_CAL	
Post-calibrated Chlorophyll <i>a</i> #	µg/l	CHLA	

- \* The SAMPLE\_DEPTH should always be used in conjunction with the LAYER\_CODE for descriptive information on where the sonde is located in the water column.
- \*\* The TOTAL\_DEPTH only applies to fixed depth sonde and is adjusted to account for the distance the sonde is fixed above the bottom.
- \*\*\* S and B layer codes are used to distinguish samples where there is both a surface and bottom instrument deployed at the same location.
- # The POST-CALIBRATED CHLOROPHYLL *a* field is currently not populated. Values will be calculated when a robust algorithm is developed.

## Appendix 9. Water Quality Mapping Parameters

W. Nelson, C. Heyer, M. Trice

Revised: 1/7/2004

Parameter	Format/Units	Field Name	Method Code
Date	Mmddyyyy	SAMPLE_DATE	
Time	hh:mm:ss (24 hr clock – EST)	SAMPLE_TIME	
Cruise Track	AAAmddyyyy (AAA = 3 Letter Trib Code)	STATION	
Tributary		WATER_BODY	
Primary Segment		PRI_SEG	
Sonde (YSI Sonde Name)	Variable Length (e.g. “Gina” or Serial Number)	SONDE	
Latitude	Decimal Degrees (NAD83)	LATITUDE	
Longitude	Decimal Degrees (NAD83)	LONGITUDE	
Sample Depth Value	meters (+)	SAMPLE_DEPTH*	
Sample Depth Code	BS = Floating Below Surface AB = Fixed Above Bottom VP = Vertical Profile	LAYER_CODE*	
Water Column Depth	meters (+)	TOTAL_DEPTH	
Boat Speed	knots	BOAT_SPEED	
Battery Voltage	volts	BATT	
Water Temperature	°C	WTEMP	F01
Specific Conductance	ms/cm	SPCOND	
Salinity (From YSI Sonde)	ppt	SALINITY	F01
Dissolved Oxygen Saturation	%	DO_SAT	F01
Dissolved Oxygen Concentration	mg/l	DO	F01
pH	su	PH	F01
Turbidity	NTU	TURB_NTU	F01
Fluorescence	% FS (FS = Full Scale)	FLUOR	
Pre-calibrated Total Chlorophyll	µg/l	TCHL_PRE_CAL	
Post-calibrated Chlorophyll <i>a</i> #	µg/l	CHLA	

\* The SAMPLE\_DEPTH should always be used in conjunction with the LAYER\_CODE for descriptive information on where the sonde is located in the water column.

# The POST-CALIBRATED CHLOROPHYLL *a* field is currently not populated. Values will be calculated when a robust algorithm is developed.

**Appendix 10. Continuous Monitoring and Water Quality Mapping Error Codes**

*C. Trumbauer, W. Nelson, C. Heyer, M. Trice, B. Cole*

Revised: 5/28/2018

Category	Code	Description	Immediate Data Impacts	Suggested Uses
Comments	CAB	Algal Bloom - No Sample Taken	Comment - No Impact on Data Value	Field Observation
Comments	CAS	Algal Sample Taken (Sample #)	Comment - No Impact on Data Value	Field Observation
Comments	CBF	Biofouling	Comment - No Impact on Data Value	
Comments	CCS	Calibration Sample Taken	Comment - No Impact on Data Value	Water Quality Mapping Specific
Comments	CDB	Disturbed Bottom	Comment - No Impact on Data Value	Field Observation
Comments	CFK	Fish Kill	Comment - No Impact on Data Value	Field Observation
Comments	CFL	Negative Fluorescence Value Not Flagged	Comment - No Impact on Data Value	Continuous Monitoring Specific
Comments	CLF	Flow Low	Comment - No Impact on Data Value	Water Quality Mapping Specific
Comments	CSC	Site Location Change	Comment - No Impact on Data Value	Continuous Monitoring Specific
Comments	CSW	Salinity Calibrated at the Wrong Level	Comment - No Impact on Data Value	
Comments	CTC	Time Change	Comment - No Impact on Data Value	NA to Data Post 2003
Comments	CTF	Temperature Probe Failure	Comment - No Impact on Data Value	
Comments	CTS	Time Skip	Comment - No Impact on Data Value	Improper Time Recording By Sonde
Comments	CTW	Turbid Water	Comment - No Impact on Data Value	Field Observation
Comments	CWD	Instrument at Wrong Depth (Depth Value)	Comment - No Impact on Data Value	Continuous Monitoring Specific

Category	Code	Description	Immediate Data Impacts	Suggested Uses
General Probe Codes	GBO	Blocked Optic	Data Invalid - Hide Data Value	Extreme Single-Point Turbidity and Chlorophyll Spikes
General Probe Codes	GNV	Negative Value	Data Invalid - Hide Data Value	
General Probe Codes	GPC	Post Calibration Out of Range	Data Invalid - Hide Data Value	

**Appendix 10. Continuous Monitoring and Water Quality Mapping Error Codes continued...**

Category	Code	Description	Immediate Data Impacts	Suggested Uses
General Probe Codes	GPF	Probe Failure	Data Invalid - Hide Data Value	
General Probe Codes	GSC	Seal Compromised	Data Invalid - Hide Data Value	
General Probe Codes	GWL	Wiper Lost	Data Invalid - Hide Data Value	
General Probe Codes	GWM	Wiper Malfunction	Data Invalid - Hide Data Value	Evident Biofouling on Optics
Non-Probe Codes	NIR	Instrument Removed	Data Invalid - Hide Data Value	Instrument Removed from Water for Short Duration (Within a Deployment)
Non-Probe Codes	NIS	Invalid Data Due To Incorrect YSI Setup	Data Invalid - Hide Data Value	
Non-Probe Codes	NND	No Data	Data Invalid - Hide Data Value	Missing Data Values
Non-Probe Codes	NNF	Ram Clogged / No Flow	Data Invalid - Hide Data Value	Water Quality Mapping Specific
Non-Probe Codes	NOW	Instrument Out of the Water	Data Invalid - Hide Data Value	
Non-Probe Codes	NPF	Power Failure	Data Invalid - Hide Data Value	
Non-Probe Codes	NQR	Data Rejected Due To QA/QC Checks	Data Invalid - Hide Data Value	
Specific Probe Codes	PDF	Depth Port Frozen	Data Invalid - Hide Data Value	
Specific Probe Codes	PDP	DO Poisoning (Anoxia)	Data Invalid - Hide Data Value	Membrane Degraded Due to Low DO
Specific Probe Codes	PSW	Salinity Calibrated at the Wrong Level	Data Invalid - Hide Data Value	

## Appendix 11. Continuous Monitoring Data Verification and Management Procedures

C. Trumbauer, M. Trice, J. Zimmerelli

Revised: 5/23/2016

*The Continuous Monitoring project currently uses two different types of instruments: YSI 6600 and EXO water quality sondess. Procedures for the two instruments are detailed below.*

### YSI 6600 Procedures

1. Open raw .DAT file in Ecowatch and rearrange parameters into the following order:  
DATE, TIME, BATT, DEPTH, TEMP, SP.COND, SALINITY, DO%, DOCONC, PH, TURBIDITY, CHL, FLUOR
2. Using the file naming convention of the station three-letter designation followed by the two-digit year and the two-digit week, export files from Ecowatch in .CDF format (e.g., JUG0718.cdf would be the 18<sup>th</sup> week of 2007).

*NOTE: If file contains BGA data, a second file must be exported containing only these BGA data because Ecowatch software can only maintain a set number of parameters and the QA/QC macro is not compatible with BGA data.*

3. Using Microsoft Excel, open the .CDF file, choosing comma delimited when prompted to identify the delimiter type.
4. Delete all data that were taken when the sonde was not in the water on station (i.e., transit time from the field office to the station). Use the logbooks to determine this time.

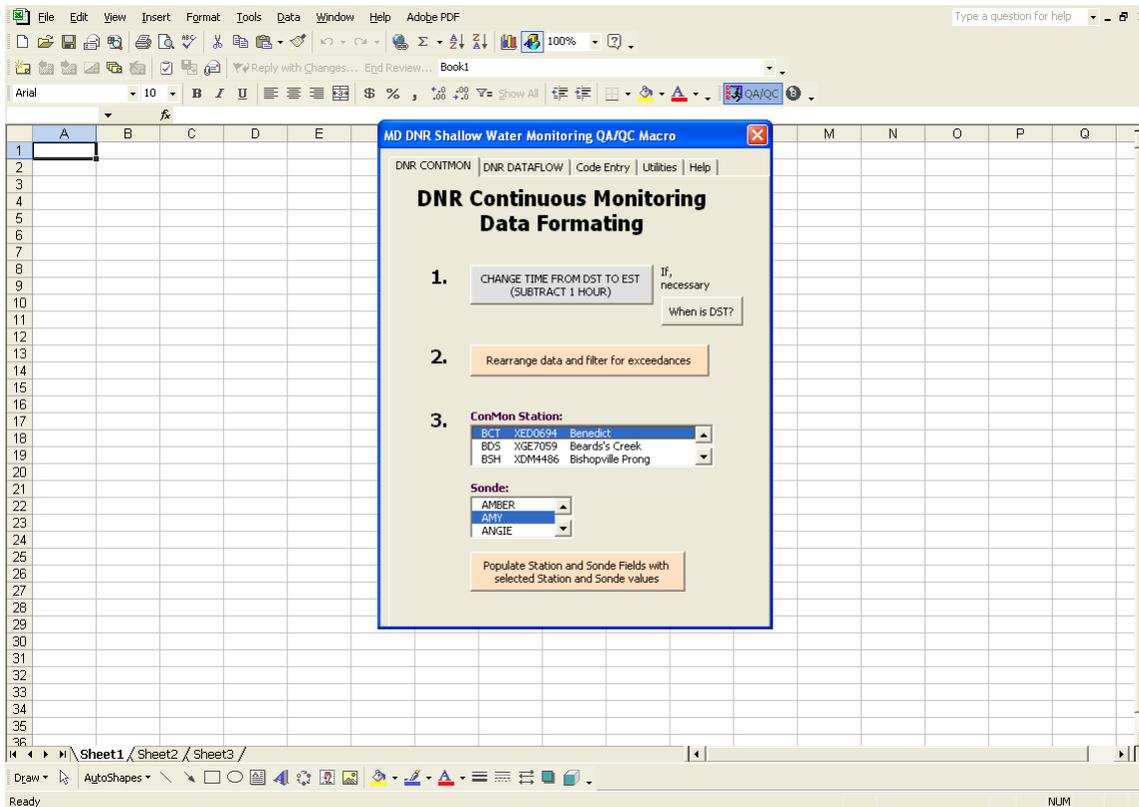
*NOTE: For BGA data files, delete all out of water data and save BGA file for inserting into web data file.*

5. If the data is from a station where the instrument is floating one meter from the surface, then delete all data in the DEPTH field (it is understood to be 1 meter at all times). If there is no column for depth, be sure to insert one in between the BATT and TEMP columns.
6. Run the QA/QC macro by clicking the “REARRANGE CONTMON DATA” button on the “DNR CONTMON” tab of the macro dialog (Figure A11\_1). When this button is clicked, the existing data columns are rearranged, new data columns are added, and error code columns are added. Error code fields are designated by the suffix “\_A”. The columns are ordered as follows:

SAMPLE\_DATE  
SAMPLE\_TIME  
STATION  
SONDE  
TOTAL\_DEPTH  
TOTAL\_DEPTH\_A  
BATT  
BATT\_A  
WTEMP  
WTEMP\_A  
SPCOND  
SPCOND\_A  
SALINITY  
SALINITY\_A

DO\_SAT  
 DO\_SAT\_A  
 DO  
 DO\_A  
 PH  
 PH\_A  
 TURB\_NTU  
 TURB\_NTU\_A  
 FLUOR  
 FLUOR\_A  
 TCHL\_PRE\_CAL  
 TCHL\_PRE\_CAL\_A  
 CHLA  
 CHLA\_A  
 COMMENTS

7. Examine the data from the previous deployment, if applicable, and note any overlapping data records resulting from the three-way *in situ* match-up. The overlapping record(s) should then be deleted from the more recent deployment to ensure that the data are continuous from deployment to deployment.

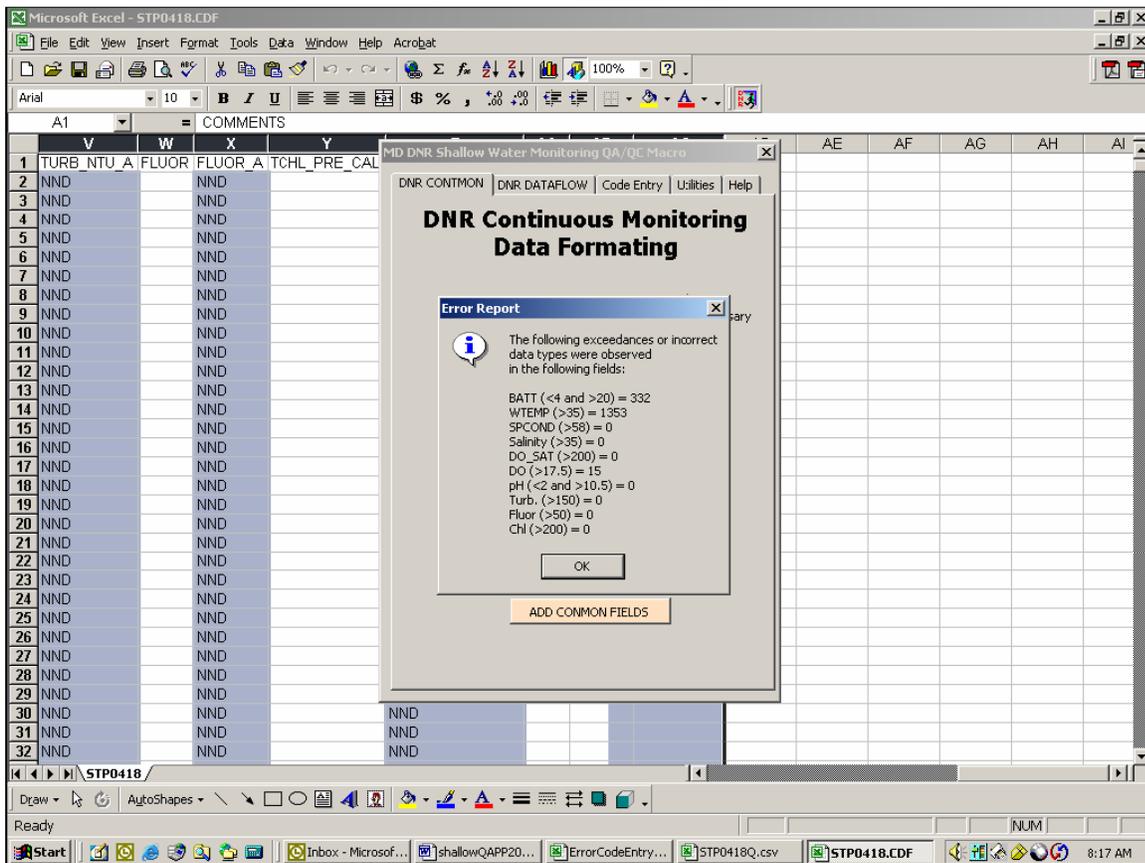


**Figure A11\_1. Screenshot of the QA/QC macro for continuous monitoring data formatting.**

8. When clicked, the “REARRANGE CONTMON DATA” button also flags negative values with the GNV error code, flags missing data with the NND error code, highlights values outside of set tolerance levels in red (Table A11\_1), and returns an overview summary of exceedances (Figure A11\_2). Tolerance levels are purposefully large to accommodate the diversity of data collected throughout Maryland’s Coastal and Chesapeake Bays.

**Table A11\_1. Tolerance levels automatically checked by the QA/QC macro.**

Parameter	Tolerance
BATT	<4 and >20
WTEMP	>35
SPCOND	>50
Salinity	>35
DO_SAT	>200
PH	>17.5
DO	<2 and >10.5
TURB	>150
FLUOR	>50
TCHL_PRE_CAL	>200



**Figure A11\_2. Screenshot of exceeded tolerances.**

9. Select the Station and Sonde information for the deployment being reviewed into the macro dialog box and click “ADD COMMON FIELDS”. This inserts the station name and sonde name into each record.

10. Flagging Values with the QA/QC Macro:

Sound data management practices dictate that data should never be deleted. As such, we employ a data management system in which all original data values are retained in the database, but erroneous data are masked with an error code (see Appendix 11 for list of error codes). Each parameter value field also has an error code field associated with it and is designated with the suffix “\_A” (e.g., DO\_A). Error codes should only be written to the error code fields. Comments should only be written to the COMMENTS field. Because the data file is comma separated, a comma should never be used to separate comments in the COMMENTS field; a semi-colon can be used instead. The following steps outline how the QA/QC Macro can be used to insert error codes and comments.

- a) Go to the “CODE ENTRY” tab of the QA/QC macro to access all of the tools necessary to enter error codes and comments in selected cells (Figure A11\_3).
- b) Use the “SELECT CELLS” box to select the cells of the spreadsheet in which you want to enter error codes or comments.
- c) After the cells have been selected, choose a “PREDEFINED CODE” or “CUSTOM CODE” by selecting the appropriate button.

*NOTE: Custom codes should only be used for comments. They should never be used for error codes because the database only recognizes predefined error codes.*

- d) Select either a “PROBE SPECIFIC”, “GENERAL PROBE”, “NON-PROBE” or “COMMENTS” code by clicking the appropriate radio button, or if applicable, type in a custom comment.
- e) Select the appropriate code and click the “ENTER CODE” button.
- f) Repeat Steps b-e as necessary.

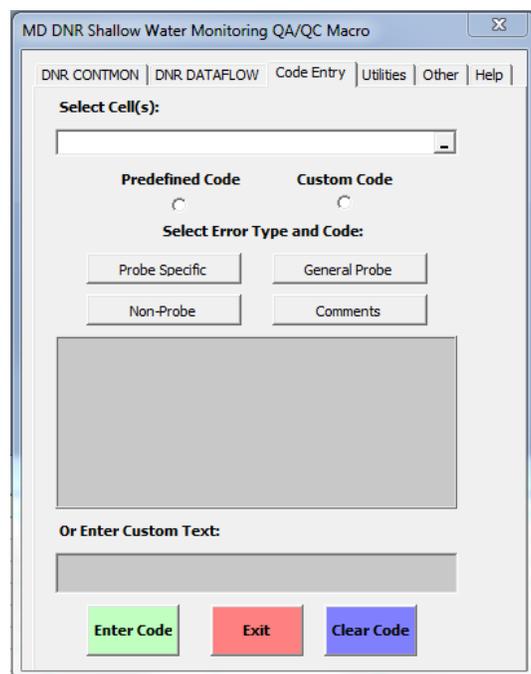


Figure A11\_3. Screenshot of QA/QC macro's code entry screen.

11. Using the procedures outlined above in Step 9 to flag data, identify any suspicious data by inspecting the values flagged in red and the original data graphed in Ecowatch. Common anomalies include abnormal spikes in chlorophyll and turbidity, abnormal dips in specific conductance, and abnormally high dissolved oxygen readings due to high dissolved oxygen charge. Post-calibration and *in-situ* field checks should also be used to identify when probes are reading incorrectly.

*NOTE: Do not be too quick to flag data. Flagging data is necessary to remove obvious outliers from the data set. Strange things can and do occur in Maryland waters, and we do not want to flag an anomaly just because it seems out of place. Anomalies should be identified, but must not be flagged unless there is proper justification. If you feel a period of data is questionable, but should not be excluded, keep it unflagged in the data set, but mention it in the comments field.*

*NOTE: All negative turbidity data is flagged by QA/QC macro. All turbidity data > or = to -5 must be recoded as verifiable data as this is within tolerance of the sensor and DNR's current standards.*

*NOTE: Specific Conductance/DO protocol. Dissolved Oxygen Concentration (DOC) is a calculated parameter which utilizes salinity in the calculation. In situations where salinity is flagged or removed due to fouling or failure, the DO concentration must be examined closely to determine its accuracy. D.O. percent saturation (DOP) is a direct reading and never deleted unless probe is determined to be failing or fouled. In systems where the Specific Conductance is less than 5000  $\mu\text{S}/\text{cm}$ , DOP and DOC are always retained. In systems higher than 5000  $\mu\text{S}/\text{cm}$ , DOP is retained and DOC must be verified using the solubility chart in the YSI manual. Generally all DOC data is retained in warmer months based on the solubility chart and DNR's current tolerances. However, when water temperatures are lower, the salinity has greater effect on DOC and can be pulled outside of DNR's tolerances.*

12. Once all of the error codes and comments have been entered into the data file, close the macro and save the file as a Comma Separated Value (.CSV) file using the same naming convention as above with a "Q" added to the end (e.g., JUG0718Q.csv).

13. Next select the Utilities tab of the QA/QC Macro and convert file to web upload format. Then select the Other tab and insert headers. Lastly, select the Utilities tab and adjust the times and then save as .CSV file without Q.

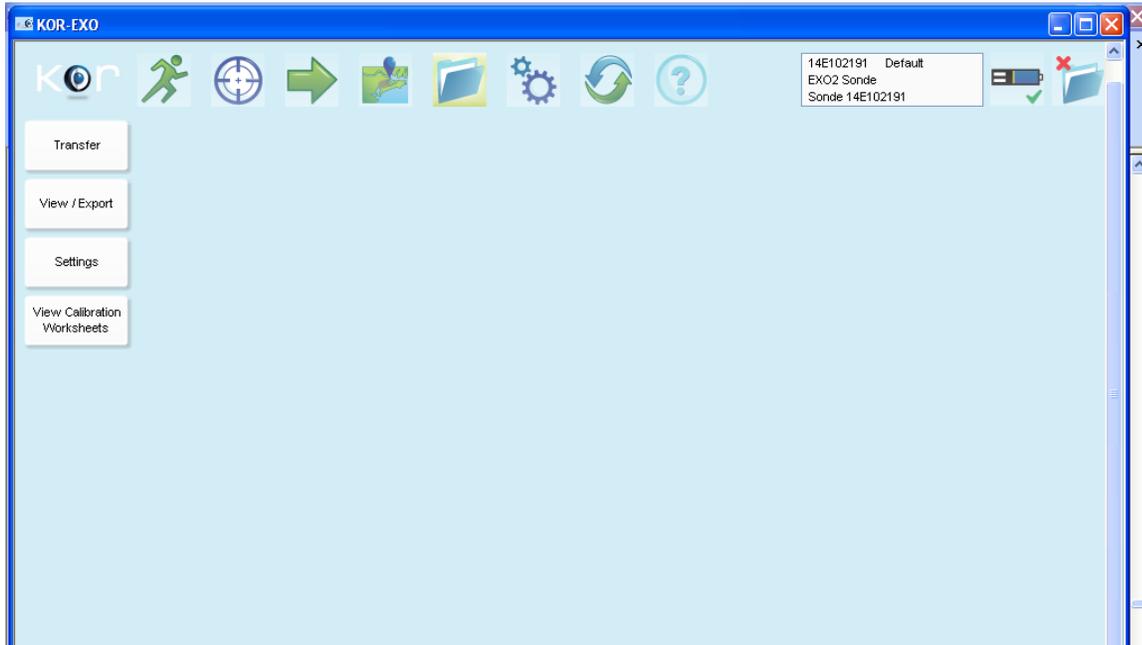
The resulting .CSV file can then be imported into DNR's database. The QA/QC'd data can also be posted to the Eyes on the Bay ([www.eyesonthebay.net](http://www.eyesonthebay.net)) website to overwrite any existing provisional real-time data.

There should be four files when a data set is complete. In our example, these files would be:

JUG0718.dat (Raw data - no editing),  
JUG0718.CDF (Raw file ready to import into excel),  
JUG0718Q.csv (Final QA/QC'd file with erroneous data masked), and  
JUG0718.csv (Web formatted file that has undergone complete QA/QC)

## YSI EXO Procedures

1. In KOR-EXO software Choose the Folder Icon “Data”. Then Choose the Transfer button.



**Figure A11\_4. Screenshot of KOR-EXO main screen.**

2. Choose the file you want from the list and click the selected button. Then Choose the View/Export Button.

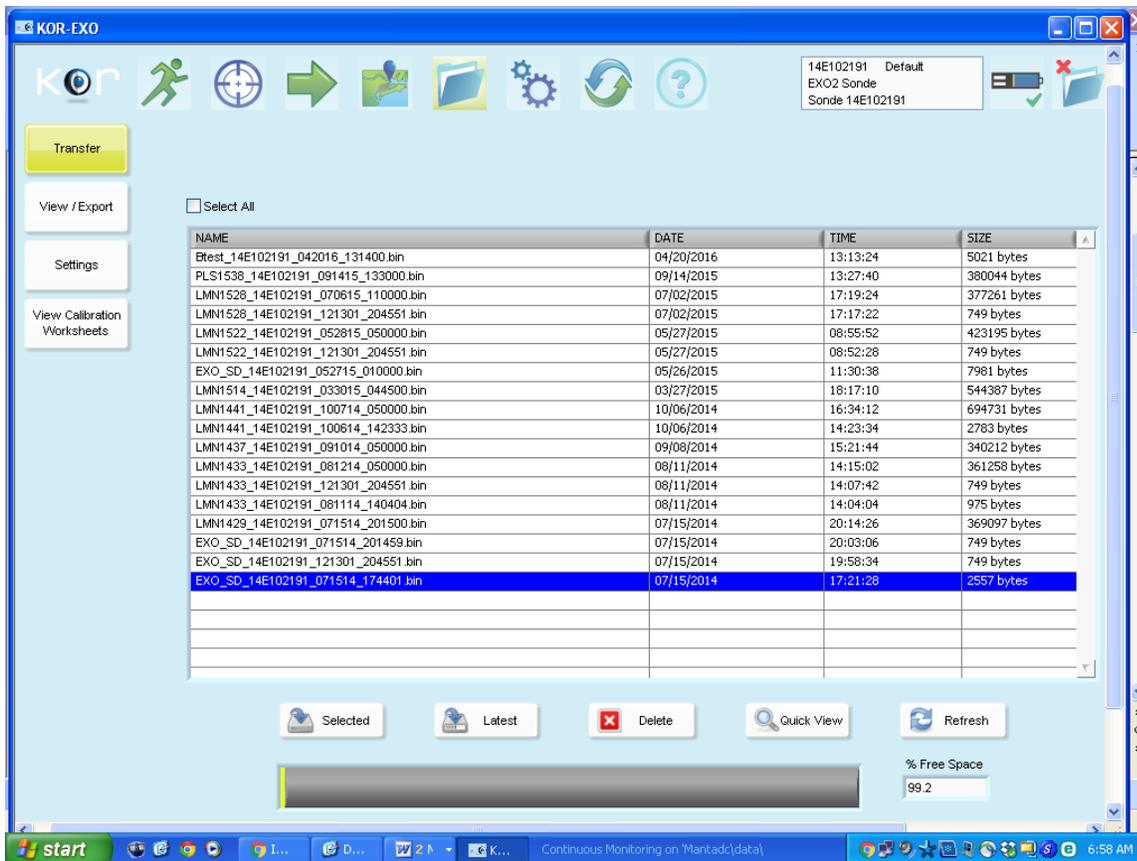
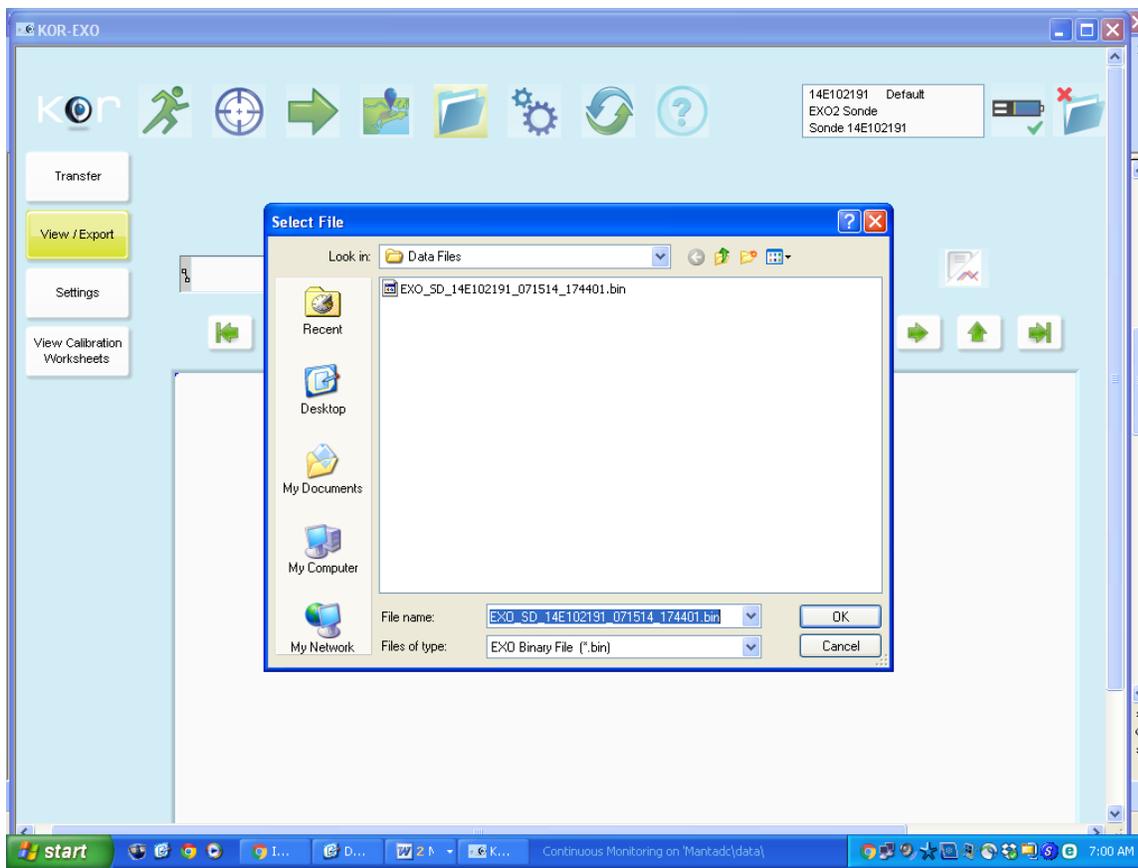


Figure A11\_5a. Screenshot of KOR-EXO select file screen.

3. Make sure when the pop up opens that the correct file is displayed in the window and choose ok.



**Figure A11\_5b. Screenshot of KOR-EXO select file screen.**

4. Once file is opened choose the Export Button. This will open up the file in EXCEL. At this point save file to the standard location for data files using standard Continuous Monitoring naming convention in the .xls format.

Using the file naming convention of the station three-letter designation followed by the two-digit year and the two-digit week. (e.g., JUG0718.cdf would be the 18<sup>th</sup> week of 2007).

*NOTE: If file contains BGA data, a second file must be exported containing only these BGA data because Ecowatch software can only maintain a set number of parameters and the QA/QC macro is not compatible with BGA data.*

5. Using Microsoft Excel, open the .xls file. Run the 2a Button.

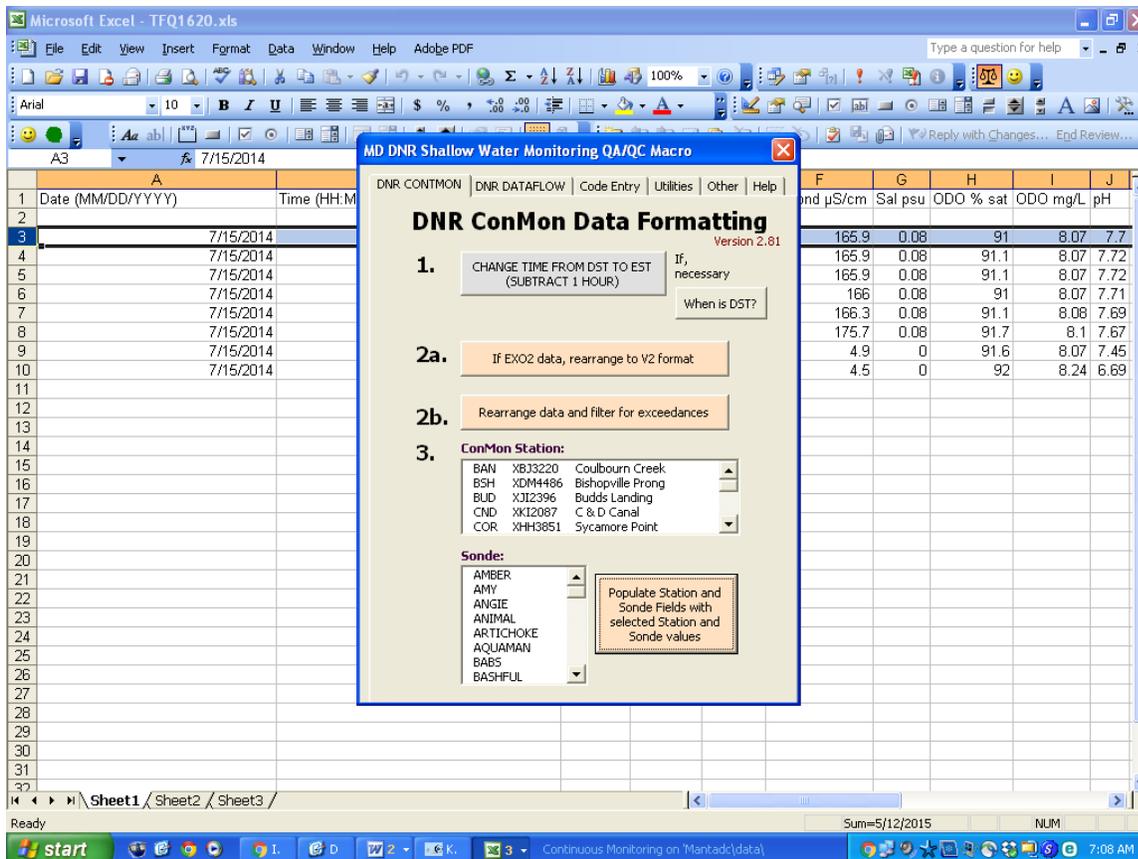


Figure A11\_6. Screenshot of QA/QC macro's code EXO entry screen.

Delete all data that were taken when the sonde was not in the water on station (i.e., transit time from the field office to the station). Use the logbooks to determine this time.

*NOTE: For BGA data files, delete all out of water data and save BGA file for inserting into web data file.*

6. Follow the procedures for YSI 6600 water quality sondes from this point.

## Appendix 12. Water Quality Mapping Data Verification and Management Procedures

W. Nelson, B. Cole, M. Trice

Revised: 5/10/2007

- 1) Open raw .txt file created by DATAFLOW / Labview Software in Excel
- 2) Use the file naming convention of the segment three-letter designation followed by the two-digit month, the two-digit day and the four-digit year and save the raw data file
- 3) Delete all data from probe/sensor warm up, until they reach equilibrium. If there is excessive (more than one minute) data collected while boat is stationary after initial start-up at boat ramp that should also be deleted. Remove all data that has no associated GPS coordinate data, or data that are instrument error codes or 'garbage' characters.
- 4) Run the QA/QC macro by clicking the "ROX sensor" box, then clicking the "REARRANGE DATAFLOW DATA" button on the "DNR DATAFLOW" tab of the macro dialog (Figure A12\_1). When this button is clicked, the existing data columns are rearranged, new data columns are added, and error code columns are added. Error code fields are designated by the suffix "\_A". The columns are ordered as follows:

SAMPLE\_DATE  
SAMPLE\_TIME  
STATION  
WATER\_BODY  
PRI\_SEG  
SONDE  
LATITUDE  
LONGITUDE  
TOTAL\_DEPTH  
TOTAL\_DEPTH\_A  
BOAT\_SPEED  
BOAT\_SPEED\_A  
BATT  
BATT\_A  
WTEMP  
WTEMP\_A  
SPCOND  
SPCOND\_A  
SALINITY  
SALINITY\_A  
DO\_SAT  
DO\_SAT\_A  
DO  
DO\_A  
PH  
PH\_A  
TURB\_NTU  
TURB\_NTU\_A  
FLUOR  
FLUOR\_A  
TCHL\_PRE\_CAL  
TCHL\_PRE\_CAL\_A

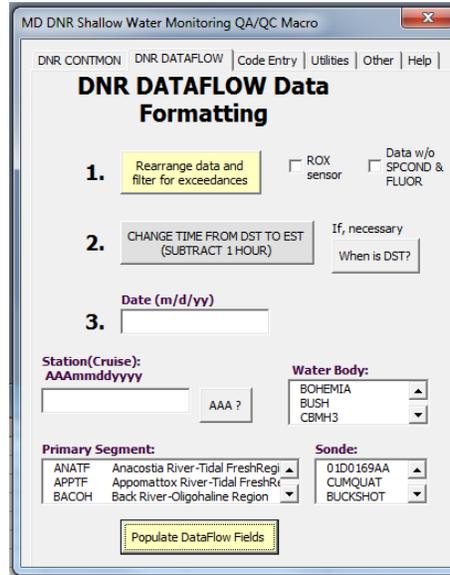


Figure A12\_1. Screenshot of the QA/QC macro for continuous monitoring data formatting.

- 5) When clicked, the “REARRANGE DATAFLOW DATA” button also flags negative values with the GNV error code, flags missing data with the NND error code, highlights values outside of set tolerance levels in red (Table A11\_1 in Appendix 11), and returns an overview summary of exceedances (Figure A11\_2 in Appendix 11). Tolerance levels are purposefully large to accommodate the diversity of data collected throughout Maryland’s Coastal and Chesapeake Bays.

Enter the Date, Station, select Water Body, select Primary Segment and select Sonde information for the deployment being reviewed into the macro dialog box and click “POPULATE DATAFLOW FIELDS”. This inserts these parameters into each record.

6) Flagging Values with the QA/QC Macro:  
Sound data management practices dictate that data should never be deleted. As such, we employ a data management system in which all original data values are retained in the database, but erroneous data are masked with an error code (see Appendix 12 for list of error codes). Each parameter value field also has an error code field associated with it and is designated with the suffix “\_A” (e.g., DO\_A). Error codes should only be written to the error code fields. Comments should only be written to the COMMENTS field. Because the data file is comma separated, a comma should never be used to separate comments in the COMMENTS field; a semi-colon can be used instead. The following steps outline how the QA/QC Macro can be used to insert error codes and comments.

- a) Go to the “CODE ENTRY” tab of the QA/QC macro to access all of the tools necessary to enter error codes and comments in selected cells (Figure A12\_1).
- b) Use the “SELECT CELLS” box to select the cells of the spreadsheet in which you want to enter error codes or comments.
- c) After the cells have been selected, choose a “PREDEFINED CODE” or “CUSTOM CODE” by selecting the appropriate button.

*NOTE: Custom codes should only be used for comments. They should never be used for error codes because the database only recognizes predefined error codes.*

- d) Select either a “PROBE SPECIFIC”, “GENERAL PROBE”, “NON-PROBE” or “COMMENTS” code by clicking the appropriate radio button, or if applicable, type in a custom comment.
  - e) Select the appropriate code and click the “ENTER CODE” button.
  - f) Repeat Steps b-e as necessary.
- 7) Using the procedures outlined above in Step 7 to flag data, identify any suspicious data by inspecting the values flagged in red and the original data graphed in Ecowatch. Common anomalies include abnormal spikes in chlorophyll and turbidity, abnormal dips in specific conductance, and abnormally high dissolved oxygen readings due to high dissolved oxygen charge. Post-calibration and *in-situ* field checks should also be used to identify when probes are reading incorrectly.

*NOTE: Do not be too quick to flag data. Flagging data is necessary to remove obvious outliers from the data set. Strange things can and do occur in Maryland waters, and we do not want to flag an anomaly just because it seems out of place. Anomalies should be identified, but must not be flagged unless there is proper justification. If you feel a period of data is questionable, but should not be excluded, keep it unflagged in the data set, but mention it in the comments field.*

- 8) Once all of the error codes and comments have been entered into the data file, close the macro and save the file as a Comma Separated Value (.CSV) file using the same naming convention as above with a “Q” added to the end (e.g., SEV05242004Q.csv).

The resulting .CSV file can then be imported into DNR’s database.

There should be two files when a data set is complete. In our example, these files would be:

SEV05242004R.csv (Raw data - no editing),  
SEV05242004Q.csv (Final QA/QC’d file with erroneous data masked)

### Appendix 13. Log of Significant Changes

MARYLAND DEPARTMENT OF NATURAL RESOURCES  
 SHALLOW WATER MONITORING (SWM) PROGRAM  
**Log of Significant Changes**

Date Initiated	Procedural Changes
2003	Beginning in 2003, YSI6026 turbidity sensors were upgraded to YSI6136 turbidity sensors. This process took two years. Since the beginning of the 2005 sampling season, turbidity data has exclusively been collected with the YSI6136.
2007	Beginning in 2007, YSI6562 dissolved oxygen sensors were upgraded to YSI6150 ROX optical sensor. This process is ongoing.
July 1, 2007	Beginning in 2007, SWM samples from the Chesapeake Bay Shallow Water Monitoring sites were no longer processed for silicates.
September 10, 2007	Upgraded Deionized Water generator to a reverse osmosis/UV system.
January 2009	Dissolved Organic Carbon (DOC) samples were collected in previous years during Continuous Monitoring and Water Quality Mapping. Beginning in 2009, DOC will cease being collected on Water Quality Mapping surveys. Continuous Monitoring DOC samples are collected only at Maryland Coastal Bay stations.
January 2010	A full suite of nutrient samples will no longer be collected from all Continuous Monitoring sites and Water Quality Mapping Surveys. Samples from six Continuous Monitoring sites and Water Quality Mapping Surveys in the Corsica River will be analyzed for the same full suite of nutrients as those measured for the Chesapeake Bay Mainstem Program (chlorophyll <i>a</i> , pheophytin, total dissolved nitrogen, particulate nitrogen, nitrite, nitrite + nitrate, ammonium, total dissolved phosphorus, particulate phosphorus, orthophosphate, particulate carbon, total suspended solids and volatile suspended solids) plus particulate inorganic phosphorus. Samples from an additional five Continuous Monitoring sites associated with the NERR System will be analyzed for a sub-set of nutrients (VSS, NH <sub>4</sub> , PO <sub>4</sub> , NO <sub>2</sub> , NO <sub>23</sub> , TN, TP), pheophytin, and chlorophyll <i>a</i> . Samples from the remaining Continuous Monitoring sites and Water Quality Mapping Surveys will be analyzed for TSS, pheophytin, and chlorophyll <i>a</i> only.
April 2010	Beginning in 2010, blank DI samples are sent to CBL to check for contamination of DI water used in filtering samples for nutrient analyses.
April 2010	Between 1998 and 2009, the older model 6562 rapid pulse dissolved oxygen probe was used in some instruments for Continuous Monitoring and Water Quality Mapping. Beginning in 2010, the 6150 ROX optical dissolved oxygen probe was used exclusively.
April 2011	Starting in 2011, water samples from the Continuous Monitoring site at Masonville Cove will be analyzed for a sub-set of nutrients (NH <sub>4</sub> , PN, PP, NO <sub>23</sub> , NO <sub>2</sub> , TSS, TN, TP), pheophytin, and chlorophyll <i>a</i> .
March 2012	Starting in 2012, water samples from the Continuous Monitoring site at Masonville Cove will be analyzed for only TSS, pheophytin, and chlorophyll <i>a</i> .
July 2014	Beginning in 2014, YSI EXO2 instruments were deployed at select sites. More EXO2 instruments are expected to replace older YSI 6600 instruments over the next several years as the SWM Program transitions to this newer technology.

April 2017	Beginning in 2017, select sites equipped with EXO2 model sondes, which possess more advanced anti-fouling technology, will have monitors deployed for up to a month at a time. Also beginning in 2017, a larger vessel, the R/V Kerhin, will be used for Water Quality Mapping cruises in the deeper, mainstem portion of CB4MH. Procedural differences between Water Quality Mapping cruises using a smaller and larger vessel are discussed in this QAPP.
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*Note: Because Shallow Water Monitoring assesses segments on a three year time scale, stations are necessarily relocated on a regular basis. Rather than include these station location changes in the Log of Significant Changes, all system sampling dates for Continuous Monitoring and Water Quality Mapping are listed in Tables 12 and 13, respectively.*

For changes in detection limits of measured parameters, see Cole and Parham (2019; Appendix XIV)

Table 12. Deployment dates for Maryland DNR Continuous Monitoring Sites.

Tributary	Station Name	Stream Code	Years deployed
Back River	Lynch Point	XIF4935	2014 2015 2016
Back River	Riverside	XIF7918	2014 2015 2016 2017 2018 2019
Big Annemessex River	Coulbourn Creek	XBJ3220	2011 2012 2013
Bohemia River	Long Point	XJI8369	2007 2008 2009
Bush River	Church Point	XJG7461	2008 2009 2010
Bush River	Lauderick Creek	XJG4337	2003 2004 2005 2006 2007
Bush River	Otter Point Creek	XJG7035	2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
C&D Canal	Back Creek	XKI2087	2015
Chesapeake Bay	Annapolis CBIBS (Buoy)	XGF7832	2011 2012
Chesapeake Bay	Arundel on the Bay	XGF5025	2017 2018 2019
Chesapeake Bay	Bay Bridge (Profiler)	XHF0488	2010
Chesapeake Bay	Bay Bridge (Profiler) - Bottom	XHF0488	2010
Chesapeake Bay	Profiler	XHG4413	2011
Chesapeake Bay	CBOS Baltimore Approach	XGF9082	2006
Chesapeake Bay	Camp Tockwogh	XJH1222	2015 2016 2017
Chesapeake Bay	Dares Beach	XEE3591	2017
Chesapeake Bay	Dares Beach Pier	XEE3691	2017 2018 2019
Chesapeake Bay	Down's Park	XHF6841	2009 2010 2011
Chesapeake Bay	Fort Howard	XIF1735	2009 2010 2011
Chesapeake Bay	Gooses Reef - Bottom (Buoy)	XEF3551	2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Chesapeake Bay	Gooses Reef – Surface (Buoy)	XEF3551	2010 2011 2012 2013 2014 2015 2016 2017 2018
Chesapeake Bay	Gratitude Marina	XHG8442	2009 2010 2011
Chesapeake Bay	Hoopers Island	XCG8862	2018 2019
Chesapeake Bay	Love Point	XHG2318	2009 2010 2011
Chesapeake Bay	Point Lookout	XBG4203	2018 2019
Chesapeake Bay	Pleasure Island	XIF3760	2015 2016 2017
Chesapeake Bay	Sandy Pt. - East Beach	XHF0561	2004 2005 2006 2007
Chesapeake Bay	Sandy Pt. - South Beach	XHF0460	2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Chesapeake Bay	Seashore Beach	XDF0255	2018 2019
Chesapeake Bay	Stump Point	XKH2870	2007 2008 2009
Chesapeake Bay	Susquehanna Flats	XKH0375	2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Chesapeake Bay	Havre de Grace	XKH2949	2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Chesapeake Bay	Tolchester	XIG2853	2015 2016 2017
Chesapeake Bay	Taylor's Island	XDG6518	2017
Chesapeake Bay	Taylor's Island Pier	XDG5922	2018 2019
Chesapeake Bay	Tilghman Island	XFF2293	2017 2018 2019
Chester River	Deep Landing	CHE0348	2003 2004 2005 2006
Chester River	Kent Narrows Inside	XGG8359	2007 2008 2009
Chester River	Kent Narrows Outside	XGG8458	2007 2008 2009

Table 12. Deployment dates for Maryland DNR Continuous Monitoring Sites, continued...

Tributary	Station Name	Stream Code	Years deployed
Chester River	Rolph's Wharf	XIH0077	2003 2004 2005 2006
Chicamacomico River	Drawbridge	CCM0069	2000 2001 2002 2003
Choptank River	High Banks	CHO0417	2006 2007 2008
Choptank River	Horn Point Lab	XEH5622	2006 2007 2008
Choptank River	Jamaica Pt	XEI7405	2006 2007 2008
Choptank River	Harris Creek (Profiler)	XFG4618	2012 2013 2014 2015 2016 2017 2018 2019
Choptank River	Harris Creek - Downstream	XFG2810	2013 2014 2015 2016 2017 2018 2019
Choptank River	Harris Creek - Upstream	XFG6431	2013 2014 2015 2016 2017 2018 2019
Choptank River	Mulberry Pt.	XFG5054	2006 2007 2008
Choptank River	Williston Lake	XFI9597	2011 2012 2013
Choptank River	Williston Lake Pier	MZC0016	2014 2015 2016 2017 2018
Corsica River	Emory Creek	XHH5046	2005 2006
Corsica River	Possum Point - Bottom	XHH4931	2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Corsica River	Possum Point - Surface	XHH4931	2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Corsica River	Sycamore Pt.	XHH3851	2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Corsica River	The Sill - Bottom	XHH4916	2006 2007 2008 2009 2010 2011
Corsica River	The Sill - Surface	XHH4916	2006 2007 2008 2009 2010 2011
Eastern Bay	CBEC	XGG6667	2005 2006 2007 2008
Eastern Bay	Hambleton Point	XFG9164	2004 2005 2006
Eastern Bay	Kent Point	XGF0681	2004 2005 2006
Elk River	Hollywood Beach	XKI0256	2007 2008 2009
Elk River	Locust Point Marina	XKI3890	2007 2008 2009
Fishing Bay	Fishing Bay	XCH8097	2003 2004 2005
Gunpowder River	APG @ Edgewood	XJG2718	2003 2004 2005
Gunpowder River	Mariners Point Park	XJF4289	2003 2004 2005
Honga River	House Point	XCG9168	2008 2009 2010
Honga River	Muddy Hook Cove	XCG5495	2008 2009 2010
Little Choptank River	Casson Pt.	XEG2646	2005 2006 2007
Little Choptank River	Gary's Creek	XEG4991	2005 2006 2007
Magothy River	Cattail Creek	CTT0014	2000 2001
Magothy River	Stonington	XHF3719	2000 2001 2002 2003
Magothy River	Whitehurst	CTT0001	2002 2003
Manokin River	Westover	XBI6387	2011 2012 2013
Middle River	Cutter Marina	MDR0038	2003 2004 2005
Middle River	Strawberry Point	FRG0002	2003 2004 2005
Nanticoke River	Sharptown	XEJ2464	2012 2013 2014
Nanticoke River	Tyaskin	XC19167	2012 2013 2014
Nanticoke River	Vienna	XDJ8905	2012 2013 2014
Northeast River	Carpenters Point	XKH2797	2007 2008 2009
Northeast River	Charlestown	XKI5022	2007 2008 2009
Patapsco River	Baltimore Harbor (Fort McHenry)	XIE5748	2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013

Table 12. Deployment dates for Maryland DNR Continuous Monitoring Sites, continued...

Tributary	Station Name	Stream Code	Years deployed
Patapsco River	Fort Armistead	XIE2581	2009 2010 2011
Patapsco River	Aquarium West	XIE7135	2016 2017 2018 2019
Patapsco River	Aquarium East - Surface	XIE7136	2016 2017 2018 2019
Patapsco River	Aquarium East - Bottom	XIE7136	2016 2017 2018 2019
Patapsco River	Fort Smallwood	XHF9808	2009 2010 2011
Patapsco River	Masonville Cove	XIE4741	2009 2010 2011 2012
Patapsco River	Masonville Cove - Bottom	XIE4741	2010 2011 2012
Patapsco River	Masonville Cove Pier	XIE4742	2013 2014 2015 2016 2017 2018 2019
Patuxent River	Benedict	XED0694	2003 2004 2005
Patuxent River	Chesapeake Biological Lab	XCF9029	2003 2004 2005
Patuxent River	Iron Pot Landing	WXT0013	2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Patuxent River	Jug Bay	PXT0455	2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Patuxent River	King's Landing	PXT0311	2003 2004 2005
Patuxent River	Mataponi	MTI0015	2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Patuxent River	Pin Oak	XDE4587	2003 2004 2005 2006 2007
Pocomoke River	(Beverly / Cedar Hall Warf)	POK0043	1999 2000 2001 2002
Pocomoke River	Rehobeth	POK0087	2000 2001 2002
Pocomoke River	Pocomoke City	POK0187	2012 2013 2014
Pocomoke River	Pocomoke Sound	XAJ5327	2012
Pocomoke River	Shelltown	POK0009	1999 2000 2001 2002 2012 2013 2014
Pocomoke River	Snow Hill	POK0316	2012 2013 2014
Potomac River	Blossom Pt	XDB4544	2006 2007 2008
Potomac River	Breton Bay (Pawpaw Point)	XCD5599	2006 2007 2008 2009
Potomac River	Fenwick	XFB0231	2004 2005 2006 2007 2008
Potomac River	Indian Head	XEB5404	2009 2010 2011 2012 2014
Potomac River	Mallows Bay Buoy	XDA8236	2018 2019
Potomac River	Mattawoman	XEA3687	2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Potomac River	Piney Point	XBE8396	2004 2005 2006 2007 2008
Potomac River	Piscataway	XFB2184	2004 2005 2006 2007 2008
Potomac River	Pope's Creek	XDC3807	2006 2007 2008
Potomac River	Port Tobacco	XDB8884	2007 2008
Potomac River	Ragged Point (Profiler)	XCE0055	2007 2008
Potomac River	Sandy Point (Profiler)	XBE5486	2009
Potomac River	Sage Point	XBF6843	2004 2005
Potomac River	St George's Creek	XBF7904	2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Potomac River	St Mary's College	XCF1440	2008 2009
Potomac River	Swan Pt.	XCC8346	2006 2007 2008
Potomac River	Wicomico Beach	XCC9680	2006 2007 2008
Rhode River	SERC	XGE3275	2004 2005 2006 2007 2009 2010 2011

Table 12. Deployment dates for Maryland DNR Continuous Monitoring Sites, continued...

<b>Tributary</b>	<b>Station Name</b>	<b>Stream Code</b>	<b>Years deployed</b>
Sassafras River	Budd's Landing	XJI2396	2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Sassafras River	Betterton	XJH2362	2006 2007 2008 2009 2010 2011
Sassafras River	Georgetown Yacht Basin	XJI1871	2006 2007
Severn River	Ben Oaks	SEV0116	2002 2003
Severn River	Sherwood Forest	XHE1973	2002 2003
South River	Beard's Creek	XGE7059	2004 2005 2006
South River	Cedar Point	XGE5984	2005
South River	Harness Cr. Downstream	ZDM0001	2004 2006 2007 2008 2011 2012
South River	Harness Cr. Upstream	ZDM0002	2004 2006 2007 2008
Transquaking River	Bestpitch	TRQ0088	2003 2004 2005
Transquaking River	Decoursey Bridge	TRQ0146	2000 2001
Tred Avon River	Tred Avon	XFG0995	2009
West River	Shady Side	XGE0284	2004 2005 2006
West River	Chesapeake Yacht Club	XGE0320	2011 2012 2013
Wicomico River	Little Monie Creek	LMN0028	2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Wicomico River	Upper Ferry	WIW0144	2006 2007 2008
Wicomico River	Whitehaven	XCJ6023	2006 2007 2008

Table 13. Maryland DNR Water Quality Mapping Systems - Years Sampled

River System	Years Sampled
Back River	2014 2015 2016
Big Annemessex River	2011 2012 2013
Bohemia River	2007 2008 2009
Bush River	2003 2004 2005
C&D Canal	2015
Corsica River	2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Chesapeake Bay/CB2OH	2015 2016 2017
Chesapeake Bay/CB3MH	2009 2010 2011
Chesapeake Bay/CB4MH	2017 2018 2019
Chesapeake Bay/CB5MH	2018 2019
Chester River	2003 2004 2005 2006
Choptank River	2006 2007 2008
Eastern Bay	2004 2005 2006
Elk River	2007 2008 2009
Fishing Bay	2003 2004 2005
Gunpowder River	2003 2004 2005
Honga River	2008 2009 2010
Little Choptank River	2005 2006 2007
Magothy River	2001 2002 2003
Manokin River	2011 2012 2013
Middle River	2003 2004 2005
Nanticoke River	2012 2013 2014
Northeast River	2007 2008 2009
Patapsco River	2009 2010 2011
Patuxent River	2003 2004 2005 2006
Pocomoke River	2012 2013 2014
Potomac River	2006 2007 2008
St. Mary's River	2004 2005 2006 2007 2008
Sassafras River	2007 2008 2009
Severn River	2001 2002 2003
South River	2004 2005 2006
Susquehanna River/CB1TF	2007 2008 2009
West/Rhode Rivers	2004 2005 2006
Wicomico River	2006 2007 2008